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Hard Single Diffraction At CDF

Presented by
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Representing

The CDF Collaboration

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Frascati, Harvard, Hiroshima,
Illinois, IPP/Canada, Johns Hopkins,
KEK, LBL, MIT, Michigan,
Michigan State, New Mexico, Osaka City,
Padova, Pennsylvania, Pittsburgh, Pisa,
Purdue, Rochester, Rockefeller, Rutgers,
Academia Sinica, Texas A&M, Texas
Tech, Tsukuba, Tufts, Wisconsin, Yale

440 people, 35 institutions, 5 countries



April 1997

International Workshop on Deep Inelastic Scattering and QCD

HARD DIFFRACTION AT CDF

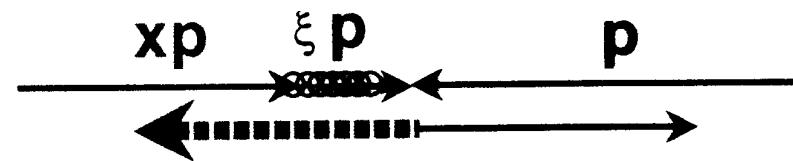
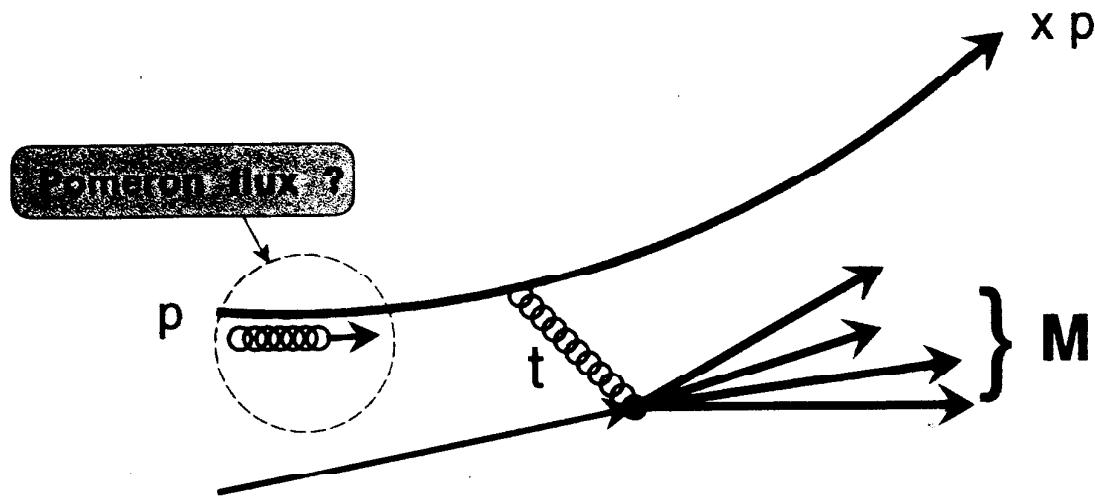
A. Using rapidity gaps

- | | |
|-----------------------------------|------------------|
| 1. Diffractive W | Accepted by PRL |
| 2. Diffractive Dijet | Submitted to PRL |
| 3. Diffractive Heavy Quark | New result |

B. Using a leading antiproton tag

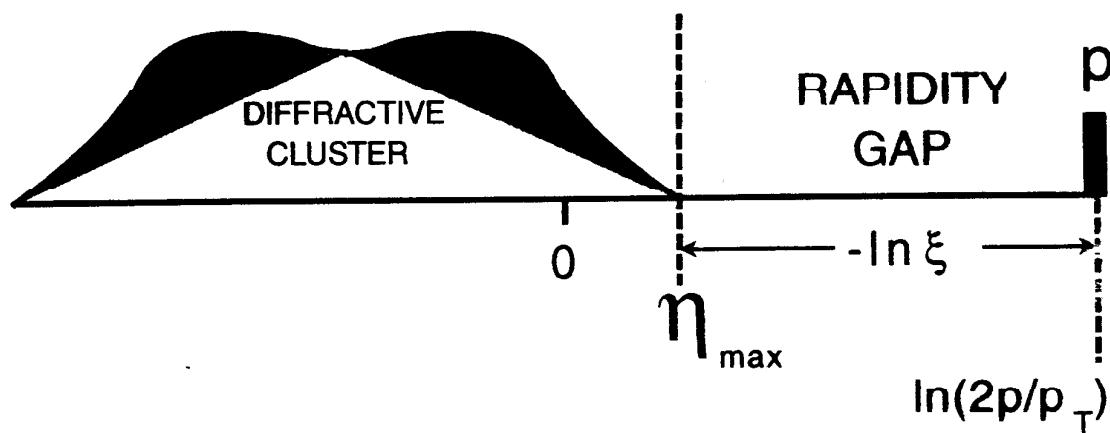
- | | |
|---|---|
| 1. Diffractive Dijet Production | Analysis completed
MC studies
Pomeron structure (?) |
| 2. Dijets in Double-Pomeron Exchange | Analysis completed
MC studies |

Diffraction Dissociation

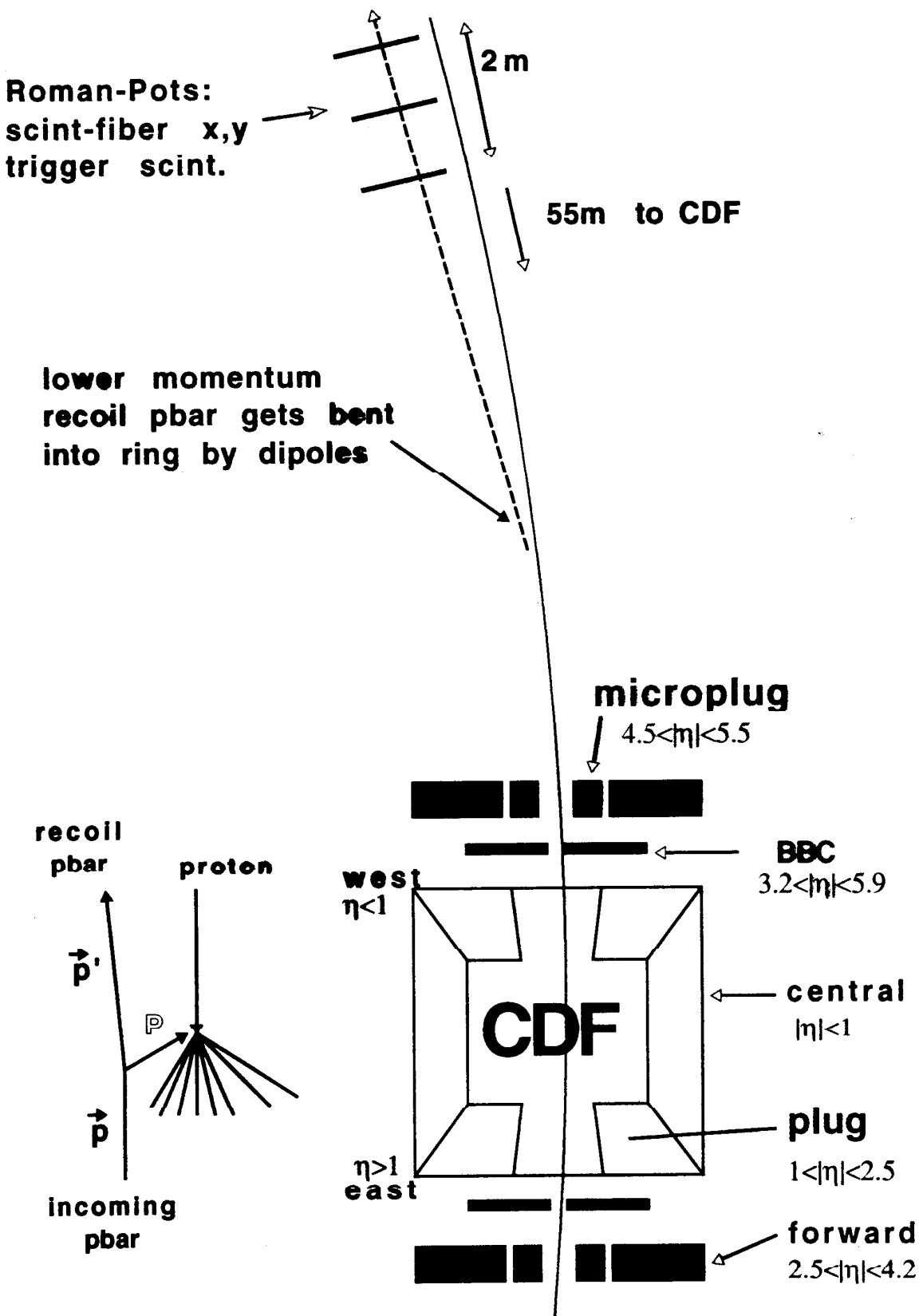


$$\xi = 1-x = M^2/s < 0.1$$

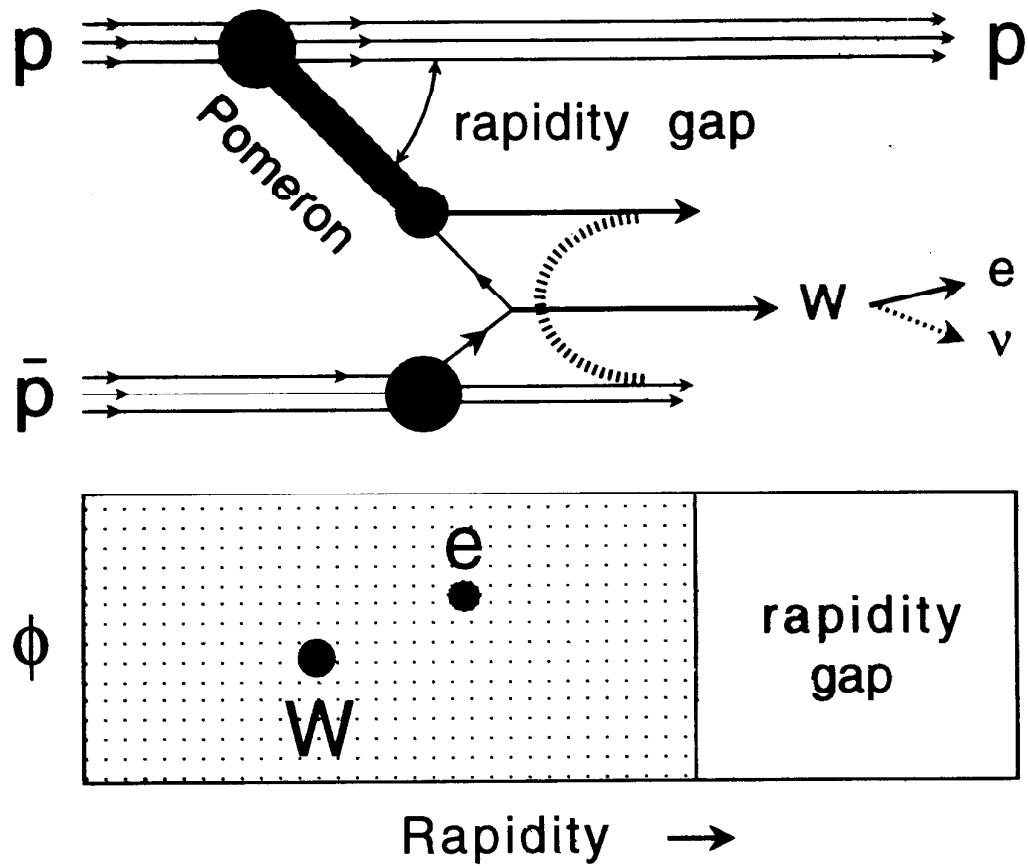
$$-\ln \xi > 2.3$$



Components of Diffractive Analysis

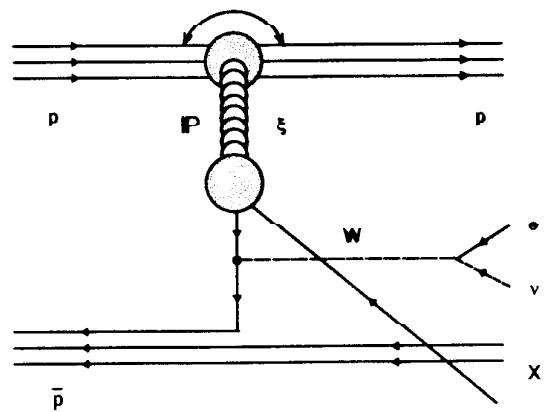


Diffractive W production



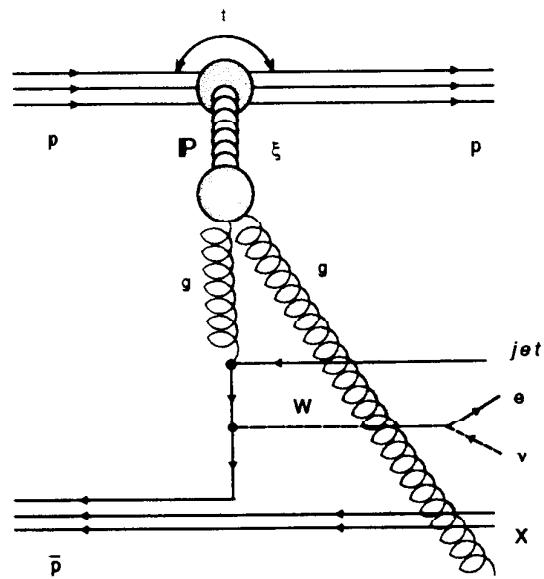
Diffractive W Production

1. Hard-quark pomeron ($\frac{6}{4} \beta (1 - \beta)$)



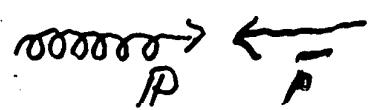
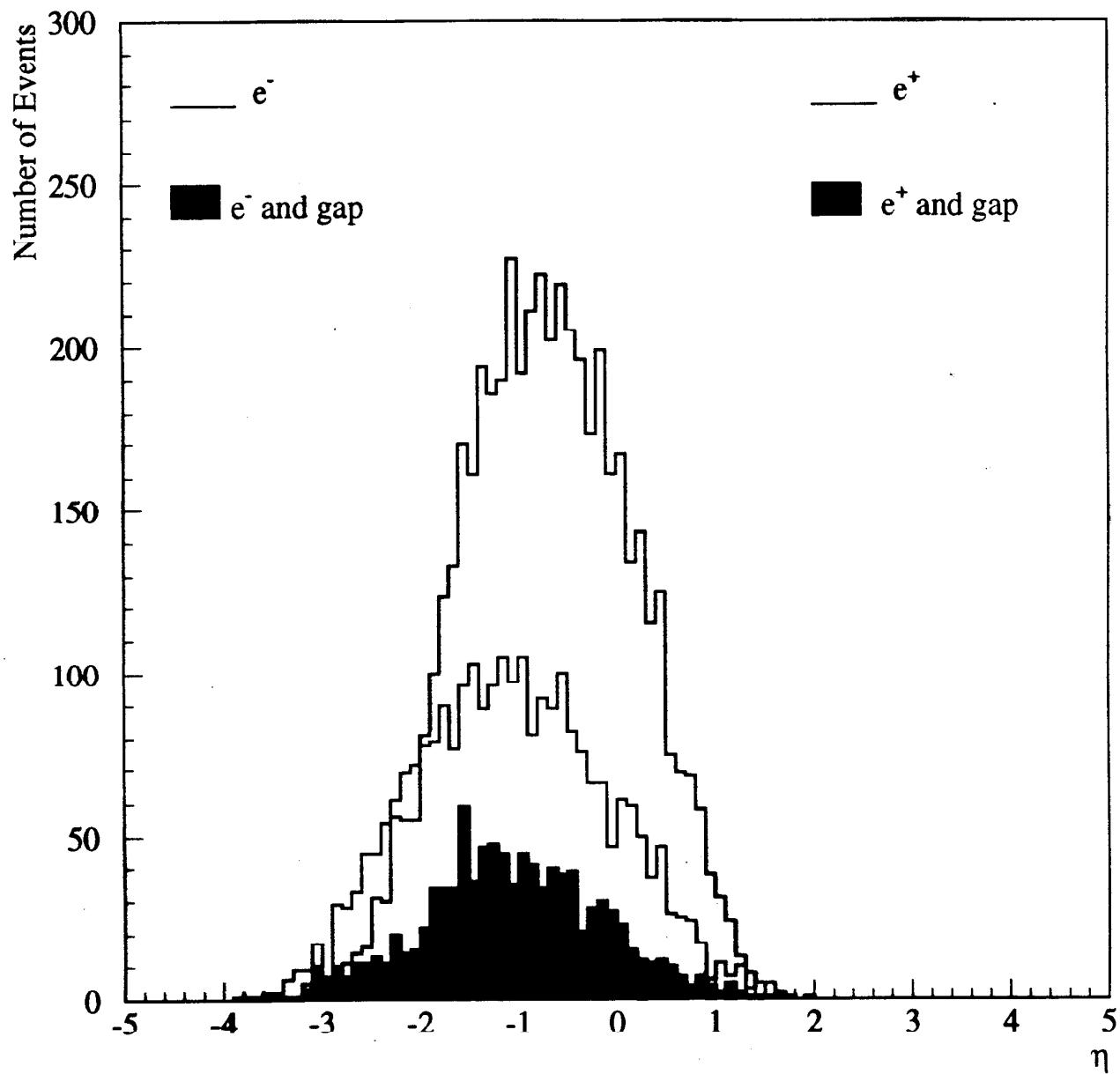
- Prediction using the standard pomeron flux: $\begin{cases} 24\% \text{ for two quark flavors} \\ 16\% \text{ for three quark flavors} \end{cases}$

2. Hard-gluon pomeron ($6 \beta (1 - \beta)$)



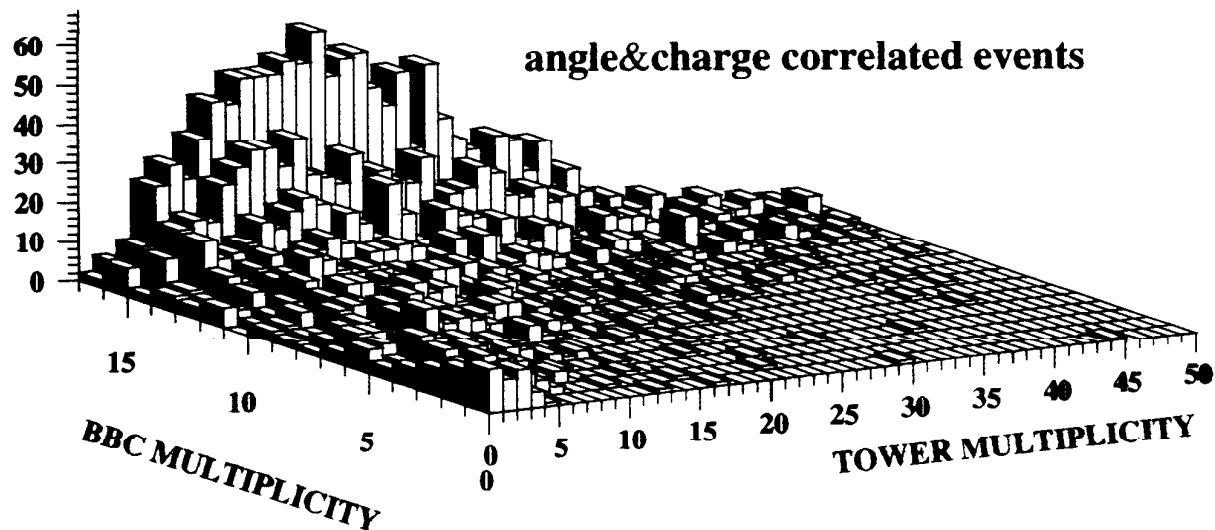
- Prediction using the standard pomeron flux: 1.1%

Hard-quark POMPYT Monte Carlo

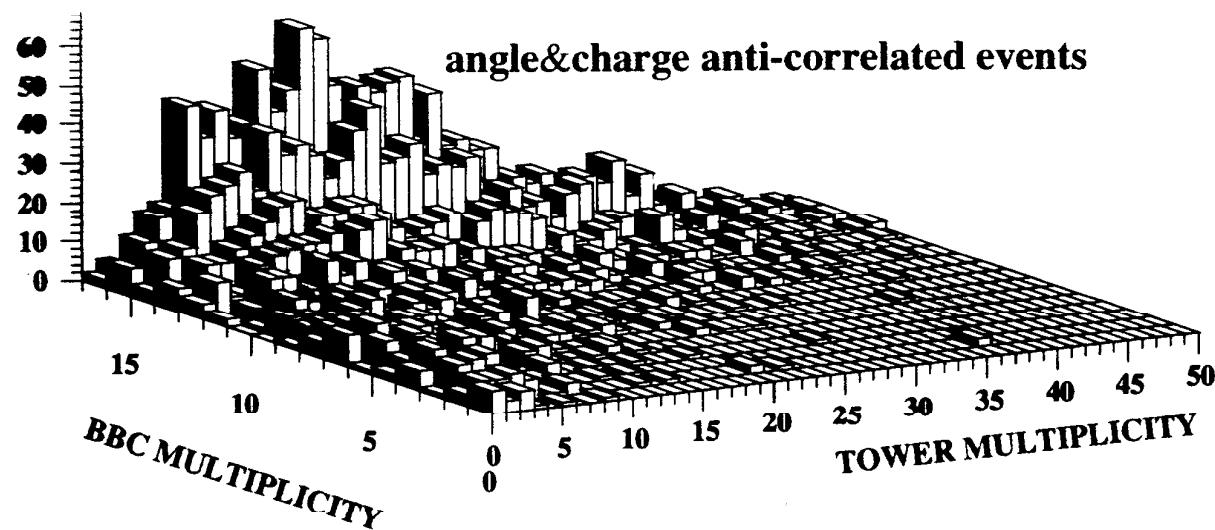


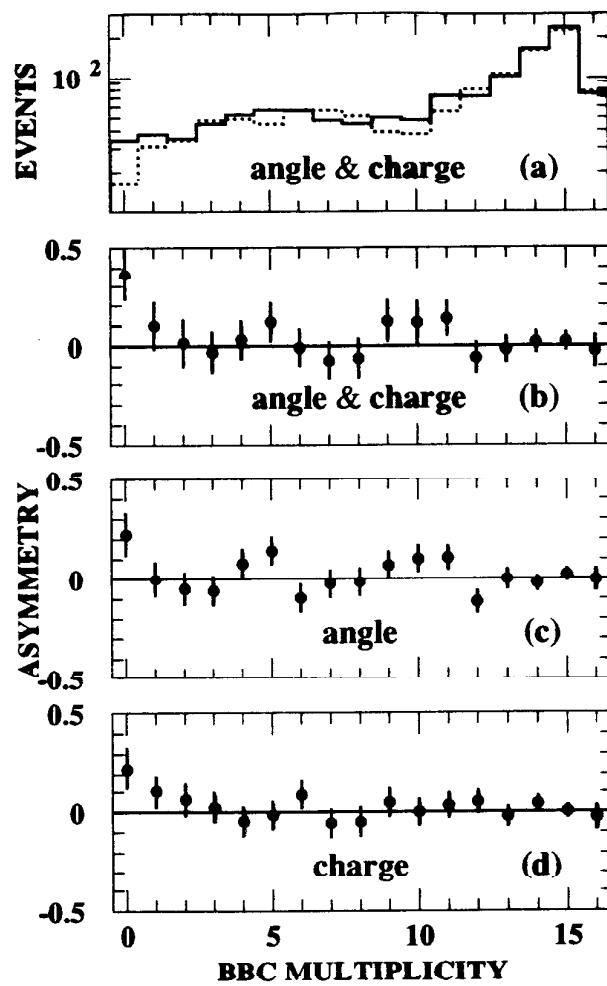
W production (CDF preliminary)

ENTRIES 4419

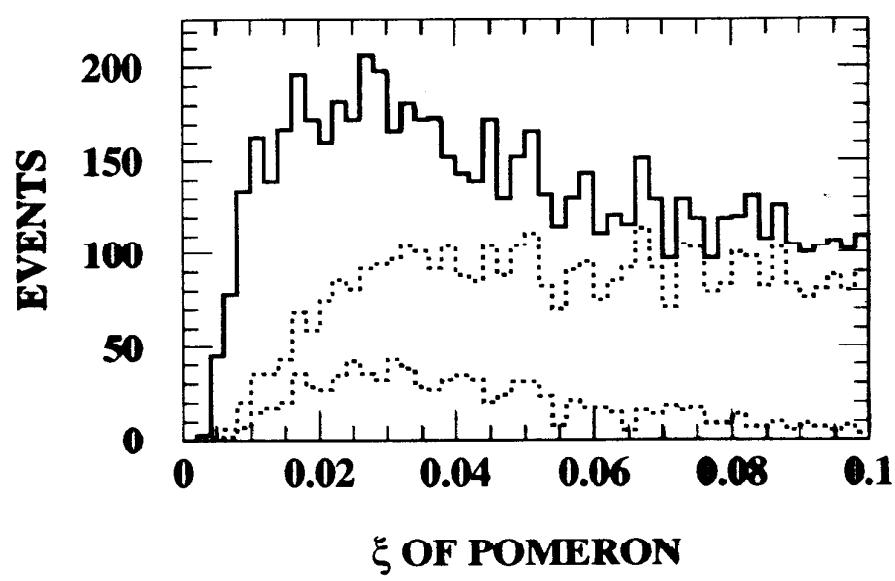


ENTRIES 4419



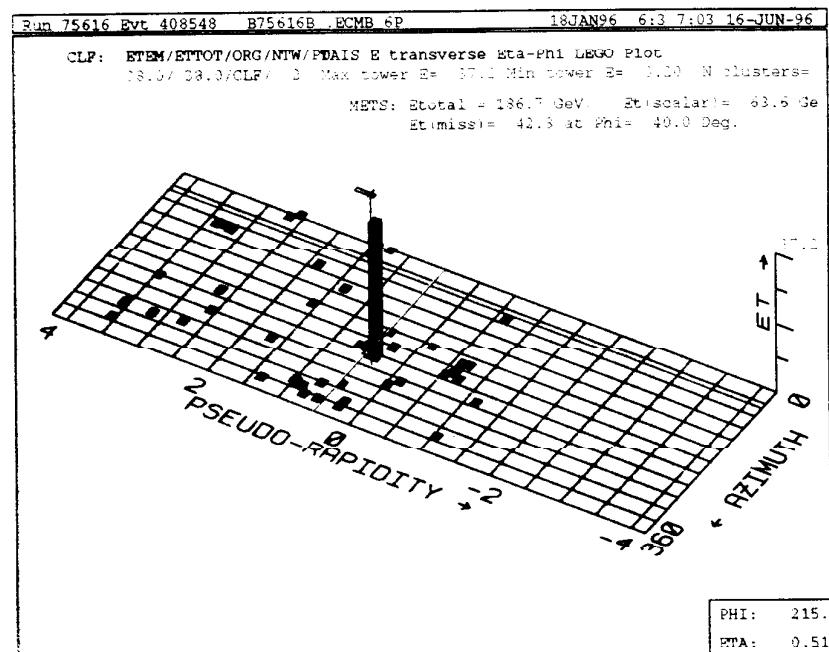
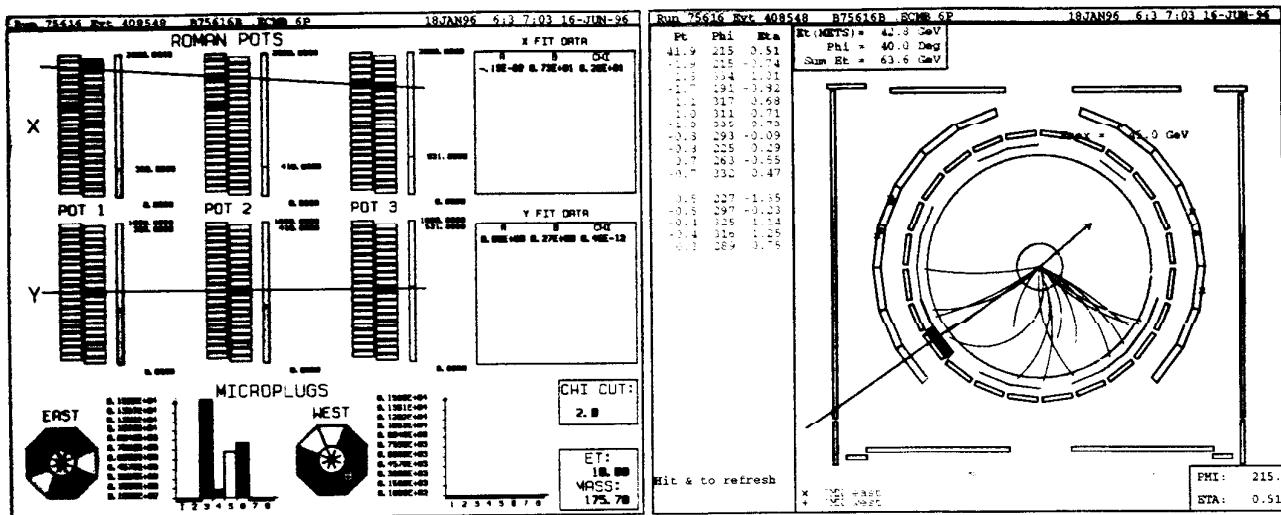


(a) Electron angle and charge doubly-correlated (solid) and anticorrelated (dashed) distributions versus BBC multiplicity, and (b) the corresponding asymmetry, defined as the bin-by-bin difference over sum of the two distributions in (a). The diffractive signal is seen in the first bin as an excess of events in the correlated distribution in (a), and as a positive asymmetry in (b). An asymmetry is also seen in the first bin of the individual angle (c) and charge (d) distributions.



Pomeron ξ distribution for all Monte Carlo generated diffractive W events (top histogram), for events with a central lepton (middle histogram), and for events with a central lepton which is (angle \otimes charge)-correlated with a BBC multiplicity of zero, one, or two hits (bottom histogram).

Diffractive W Candidate Event



RESULTS ON DIFFRACTIVE W PRODUCTION

- Diffractive to non-diffractive ratio:

$$R_W = [1.15 \pm 0.51(\text{stat}) \pm 0.20(\text{syst})]\% = (1.15 \pm 0.55)\%$$

- POMPYT prediction with standard pomeron flux:

Full hard-quark structure: 24% (16%) for two (three) quark flavors.

Full hard-gluon structure: 1.1%

- Hard-quark pomeron structure favored by the low fraction of diffractive $W + \text{Jet}$ events observed.

- POMPYT prediction with renormalized flux:

Full hard-quark structure: 2.7% (1.8%) for two (three) quark flavors.

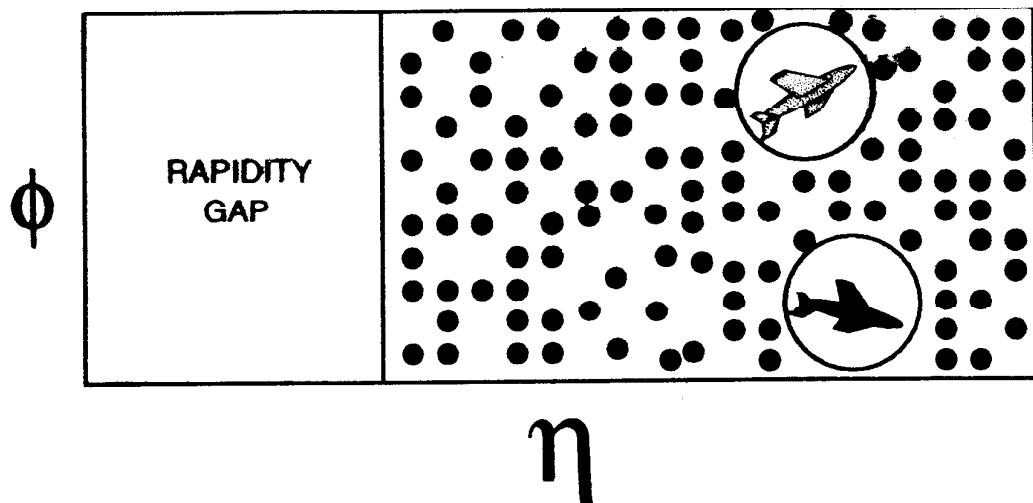
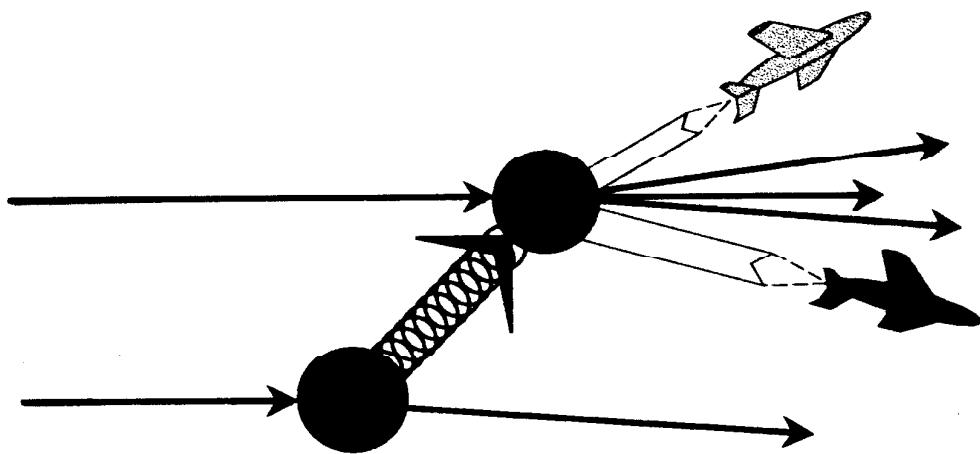
Full hard-gluon structure: 0.1%

- Hard-quark fraction of pomeron structure:

Using renormalized flux: $f_q = 0.4 \pm 0.2$ (0.6 ± 0.3) for two (three) quark flavors.

- Compare with ZEUS: $0.2 < f_q < 0.7$

DIFFRACTIVE DIJETS



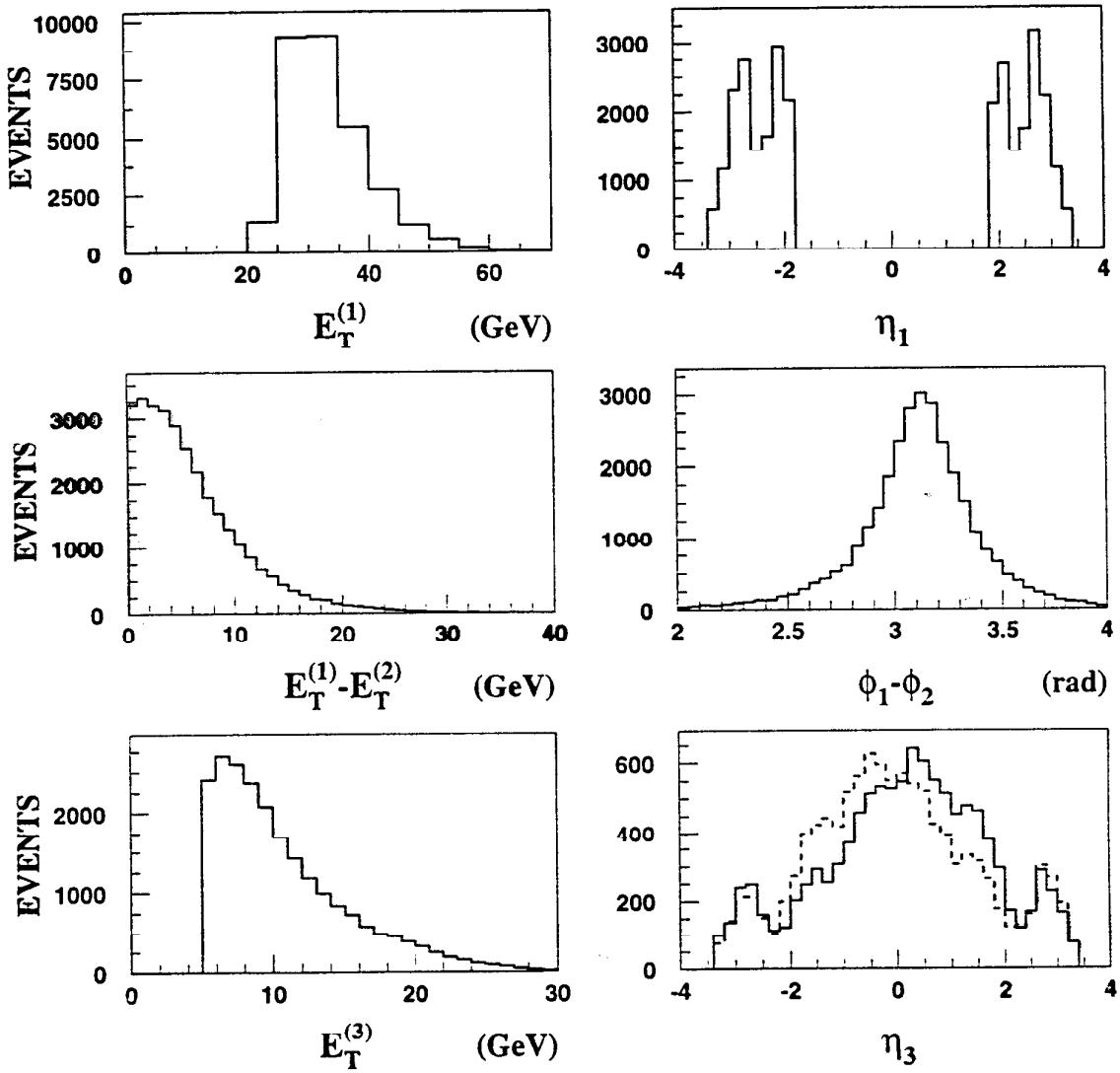


FIG. 1. (*top*) Leading jet transverse energy and pseudorapidity; (*middle*) difference between the transverse energies and azimuthal angles of the two leading jets; (*bottom*) third jet ($E_T^{(3)} > 5$ GeV) transverse energy and pseudorapidity (solid/dashed line for events with the two leading jets at positive/negative η).

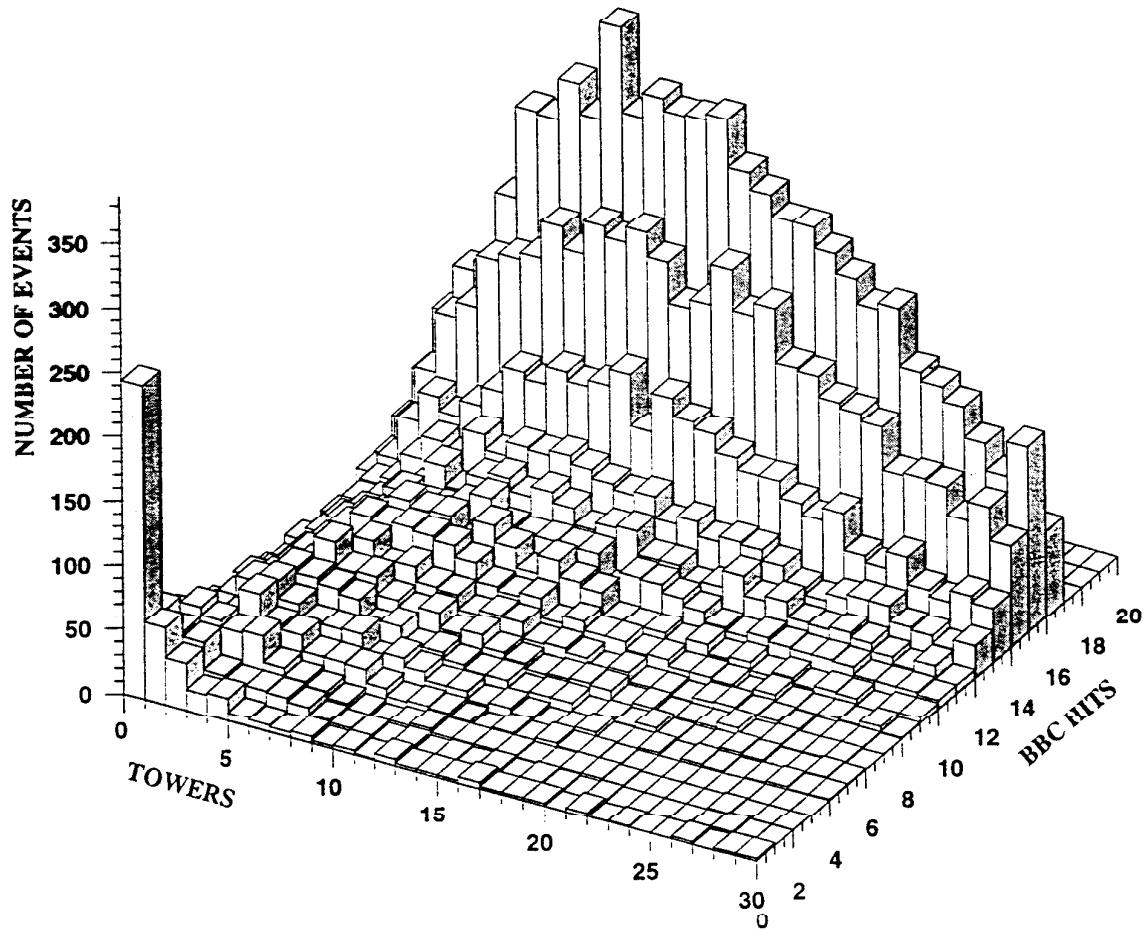


FIG. 2. Beam-beam counter multiplicity (BBC hits) versus forward calorimeter tower multiplicity in the pseudorapidity regions $3.2 < |\eta_{(BBC)}| < 5.9$ and $2.4 < |\eta_{(TOWER)}| < 4.2$ opposite the dijet system.

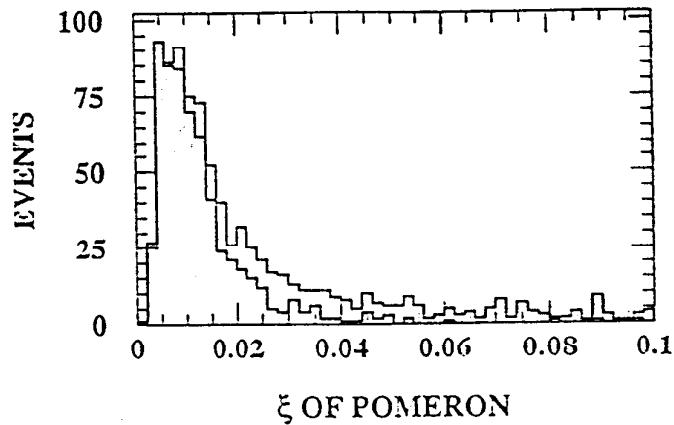


Figure 1: Pomeron ξ distribution for diffractive dijet events with jet $E_T > 20$ GeV and $1.8 < |\eta| < 3.5$ generated by POMPYT using a hard-gluon pomeron structure. The shaded area represents the subset of Monte Carlo events with zero BBC and forward calorimeter multiplicities, corresponding to the data in the (0,0) bin of Fig. 2.

ACCEPTANCE CORRECTIONS

Rapidity gap acceptance	0.70 ± 0.03
Single-vertex efficiency (ND)	0.58 ± 0.05
Single-vertex efficiency (SD)	0.86 ± 0.03
BBC \oplus FCAL live time	0.85 ± 0.02

RESULT

$$R_{GJJ} = [0.75 \pm 0.05(stat) \pm 0.09(syst)]\% = (0.75 \pm 0.10)\%$$

$$(E_T^{jet} > 20 \text{ GeV}, |\eta|^{jet} > 1.8, \eta_1 \eta_2 > 0, \xi < 0.1)$$

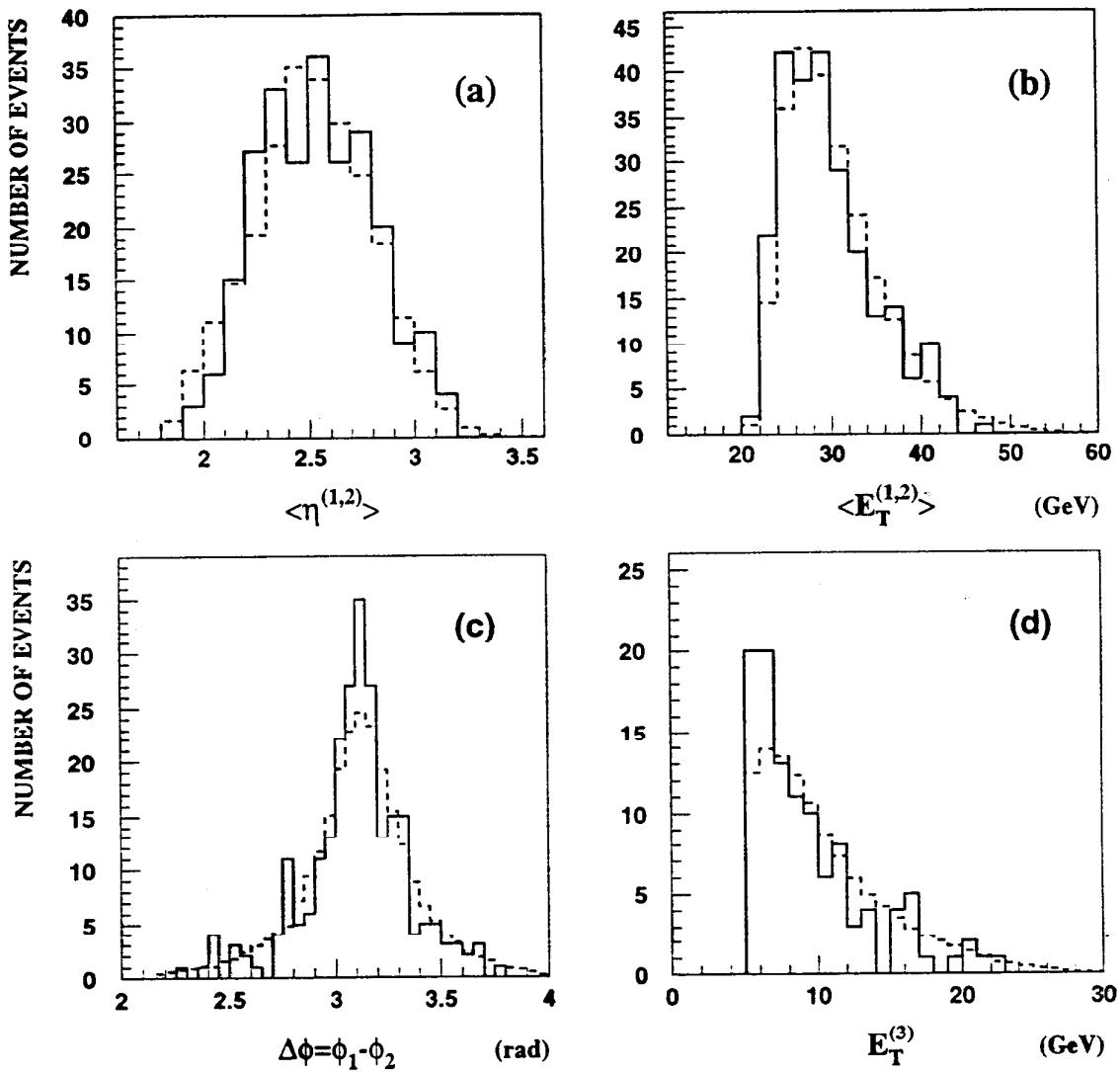


FIG. 3. Comparison of diffractive (solid) with normalized non-diffractive (dashed) event distributions: (a) average pseudorapidity, (b) average transverse energy and (c) azimuthal angle difference of the two leading jets, and (d) transverse energy of the third jet. The diffractive event sample is from the 0-0 bin of Fig. 2, which contains approximately 20% non-diffractive background.

The Third Jet

Fraction of events with a third jet of $E_T > 5 \text{ GeV}$

Event sample	Fraction	Pomeron structure
Diff. data	0.45	
Non-diff. data	0.73	
$\frac{\text{diff. data}}{\text{non-diff. data}}$	0.62 ± 0.05	
$\frac{\text{diff. MC}}{\text{non-diff. MC}}$	0.38	$(f_g = 0, f_q = 1)$
$\frac{\text{diff. MC}}{\text{non-diff. MC}}$	0.89	$(f_q = 0, f_g = 1)$
$\frac{\text{diff. MC}}{\text{non-diff. MC}}$	0.73 ± 0.11	$(f_g = 0.7 \pm 0.2, f_q + f_g = 1)$

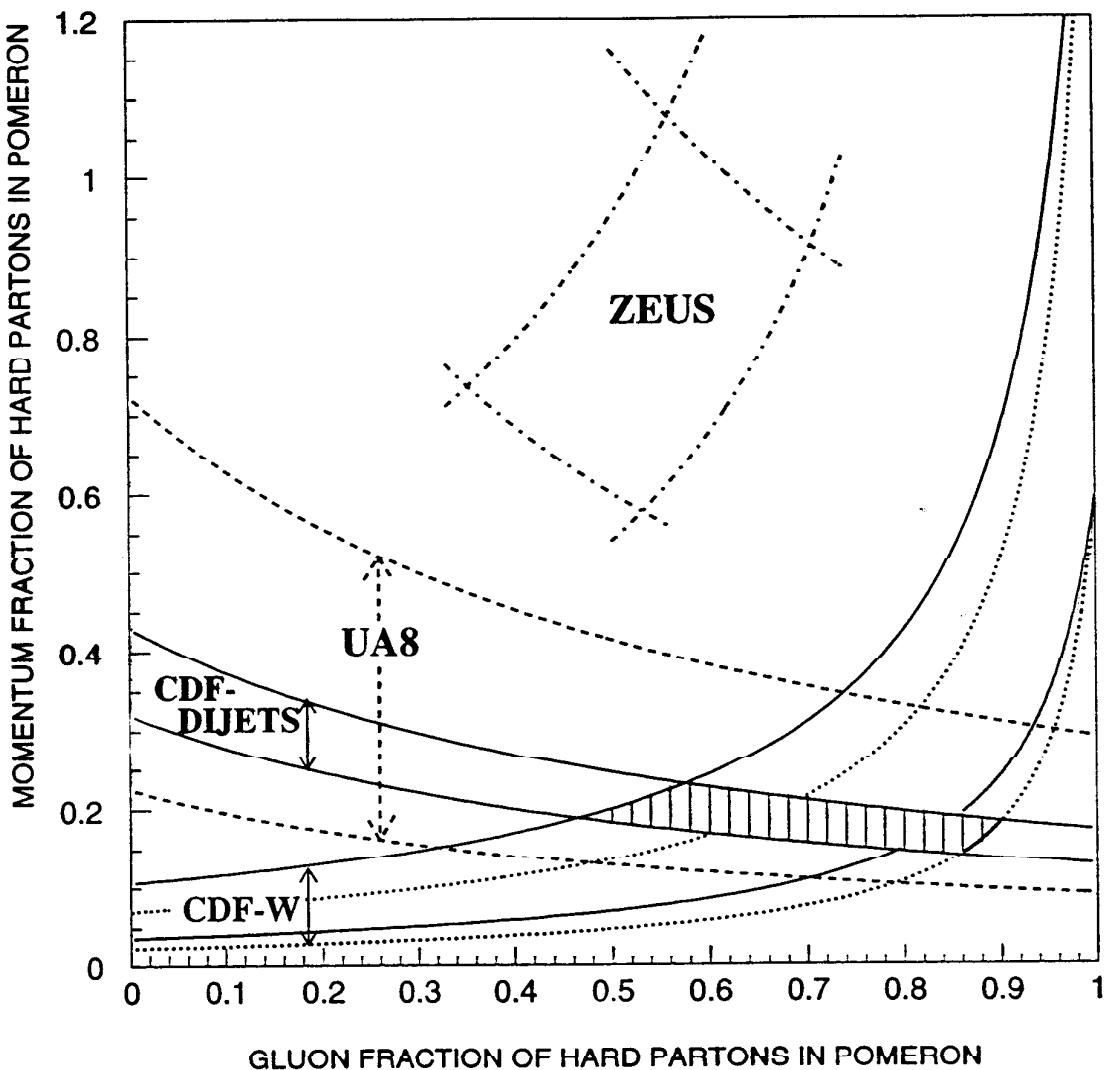


FIG. 5. Momentum fraction versus gluon fraction of hard partons in the pomeron evaluated by comparing measured diffractive rates with Monte Carlo predictions based on the standard pomeron flux and assuming that only hard pomeron partons participate in the diffractive processes considered. Results are shown for ZEUS (dashed-dotted), UA8 (dashed) and the CDF-DIJET and CDF-W measurements. The CDF W result is shown for two (dotted) or three (solid) light quark flavors in the pomeron. The shaded region is used in the text to extract the quark to gluon fraction of the pomeron and the standard flux discrepancy factor.

Diffractive Heavy Quark

- Inclusive e^- sample $E_T > 7 \text{ GeV}$
 - ~ 71K events passing e^- quality cuts
 - residual ~ 22% $\gamma \rightarrow e^+ e^-$ conversions
 - ~ 13% hadron faking e^-

i.e. -65% b+c

$$\bullet R_{HQ} = \frac{\text{diff } (b+c)}{\text{incl } (b+c)} = [0.18 \pm 0.03 \text{ (stat)}] \%$$

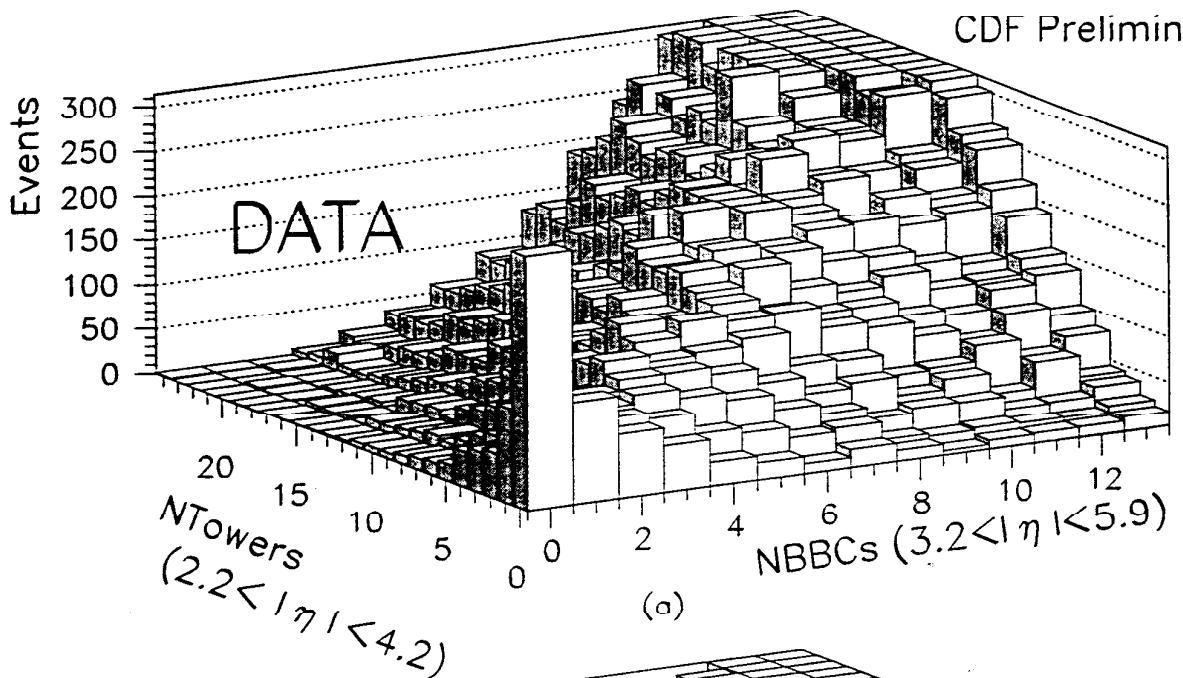
$$|\eta^e| < 1.1 \quad 7 < E_T^e < 20 \text{ GeV}$$

not corrected for gap acceptance

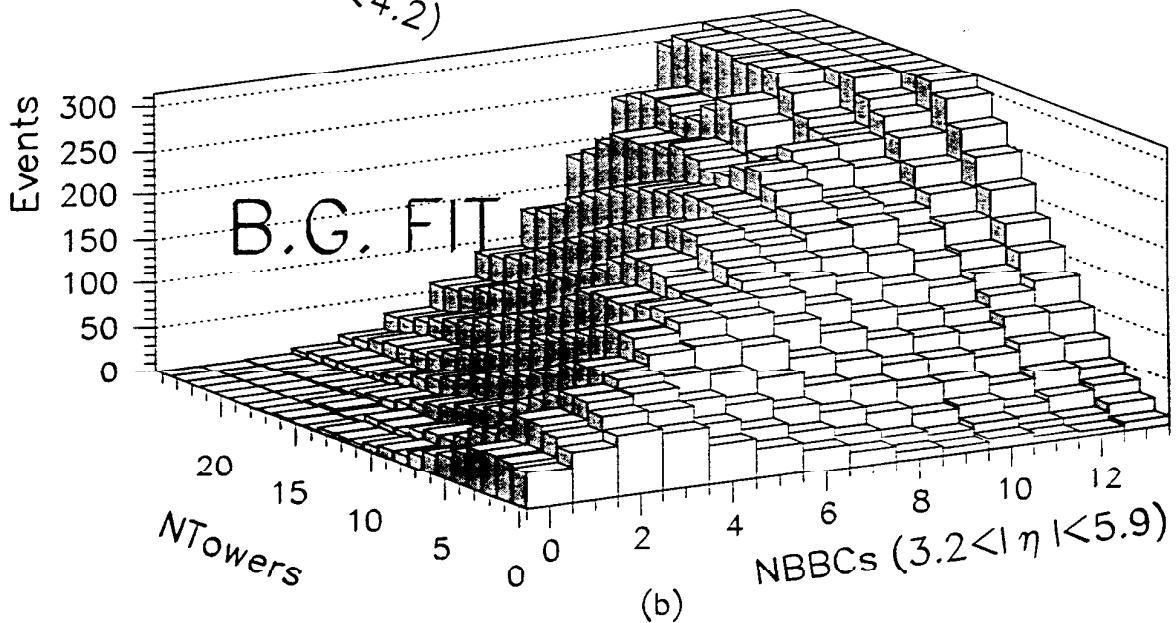
Diffractive signals

electron
sample

CDF Preliminary



(a)



(b)

Figure 1: (a) Correlation of N_{BBC} , and N_{towers} in the same rapidity side. West and east side is overwritten in one plot. (b) Background shape fitted with $N_{BBC} > 0$ and $N_{towers} > 0$.

e^+ - sample
with gap

Diffractive sample composition
CDF preliminary

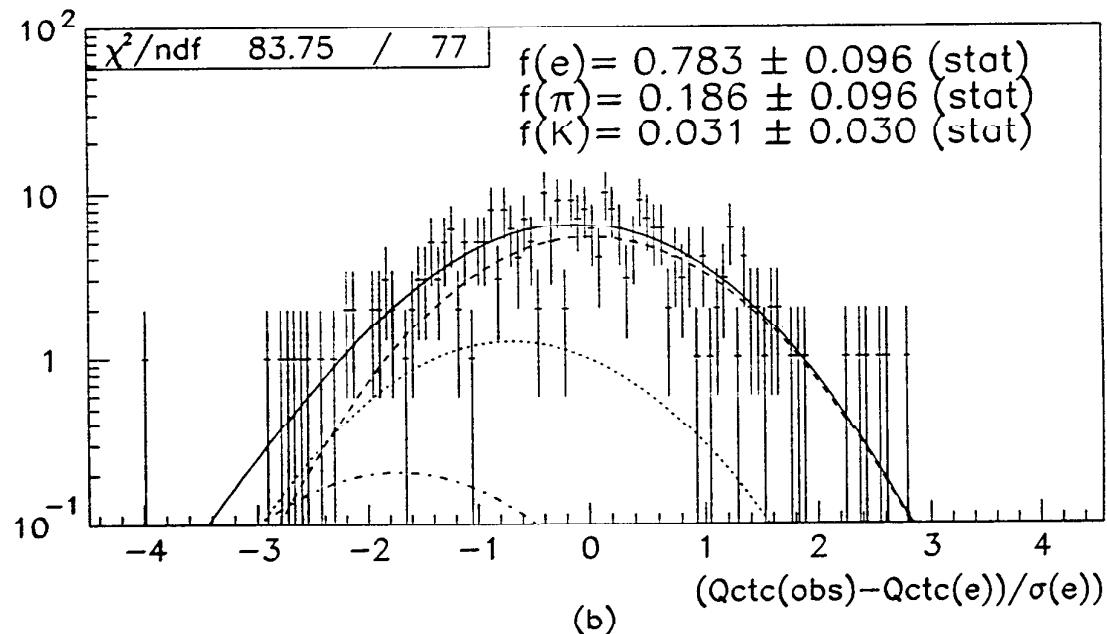
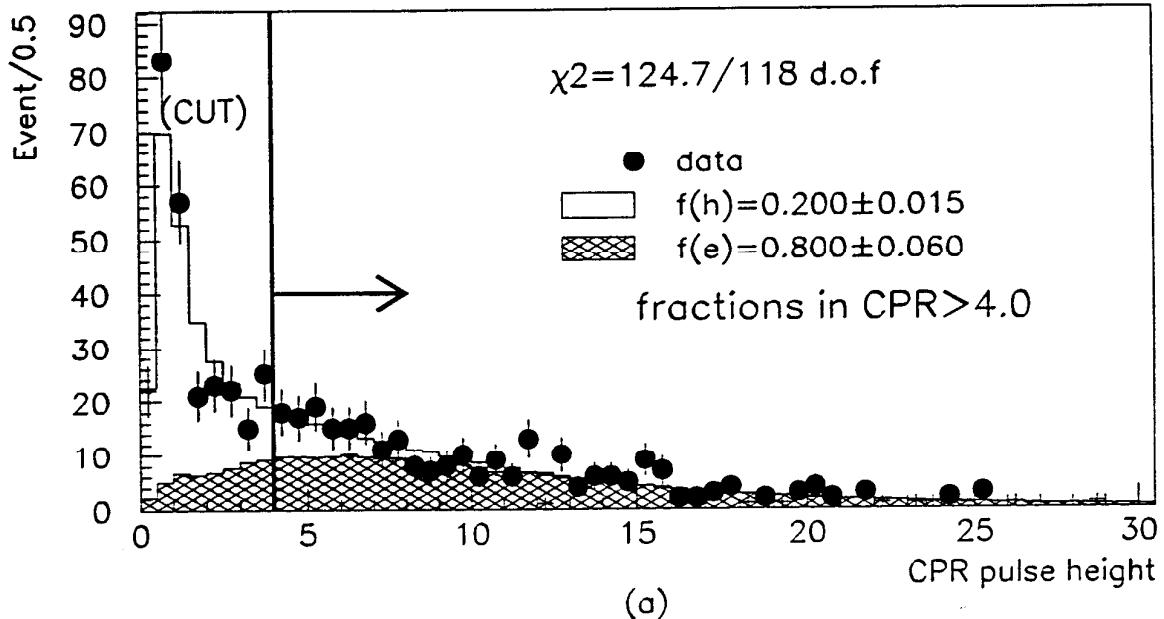


Figure 8: (a) CPR distribution of the diffractive sample. (b) dE/dx distribution of the diffractive sample.

e^{+-} sample
with gap

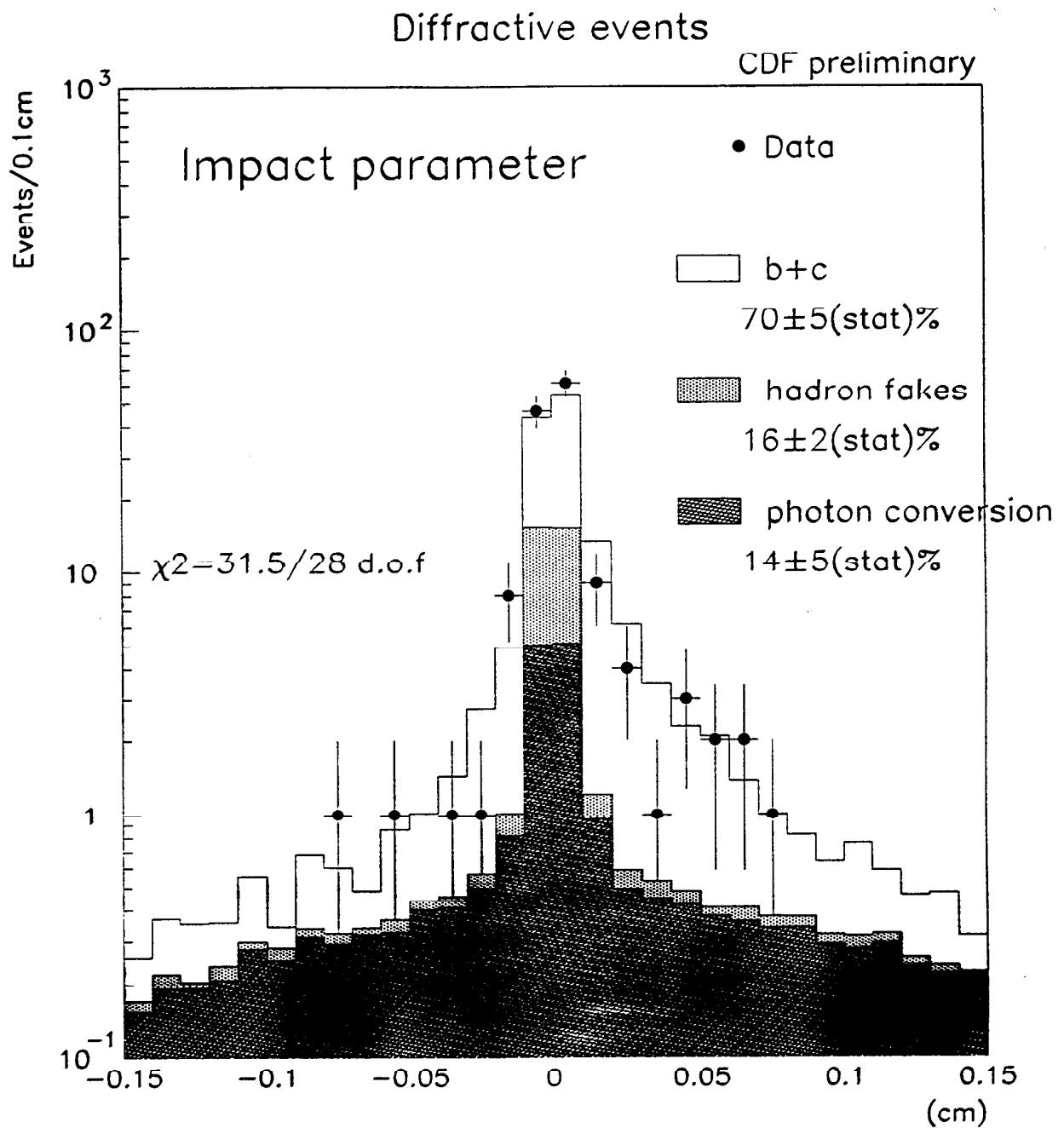
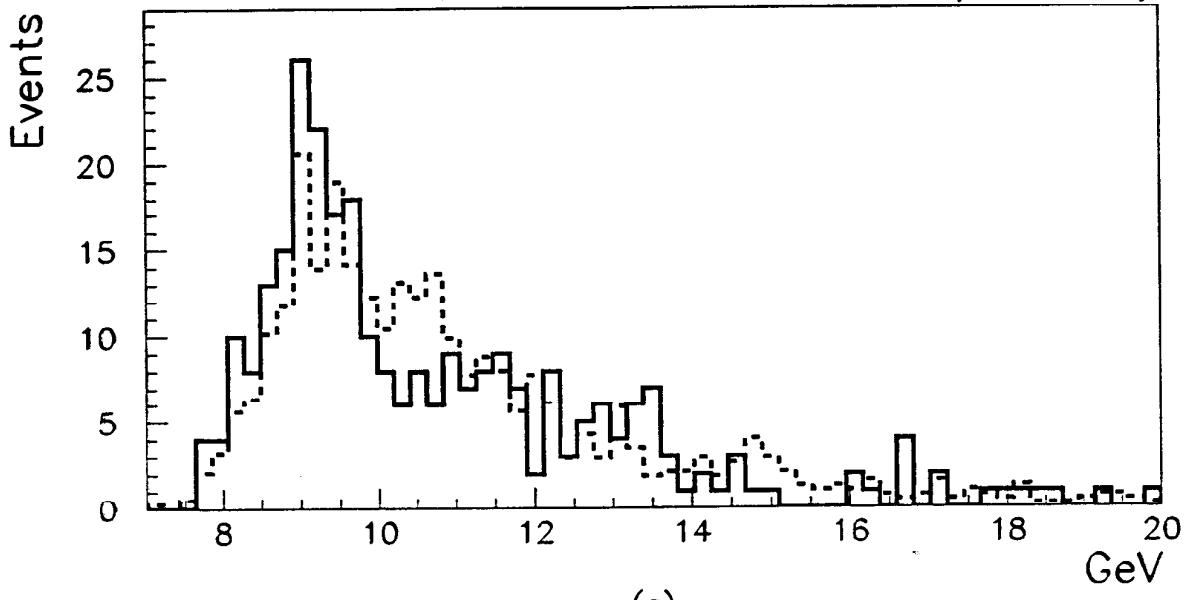


Figure 16: Signed impact parameter distribution of the diffractive electron candidates.

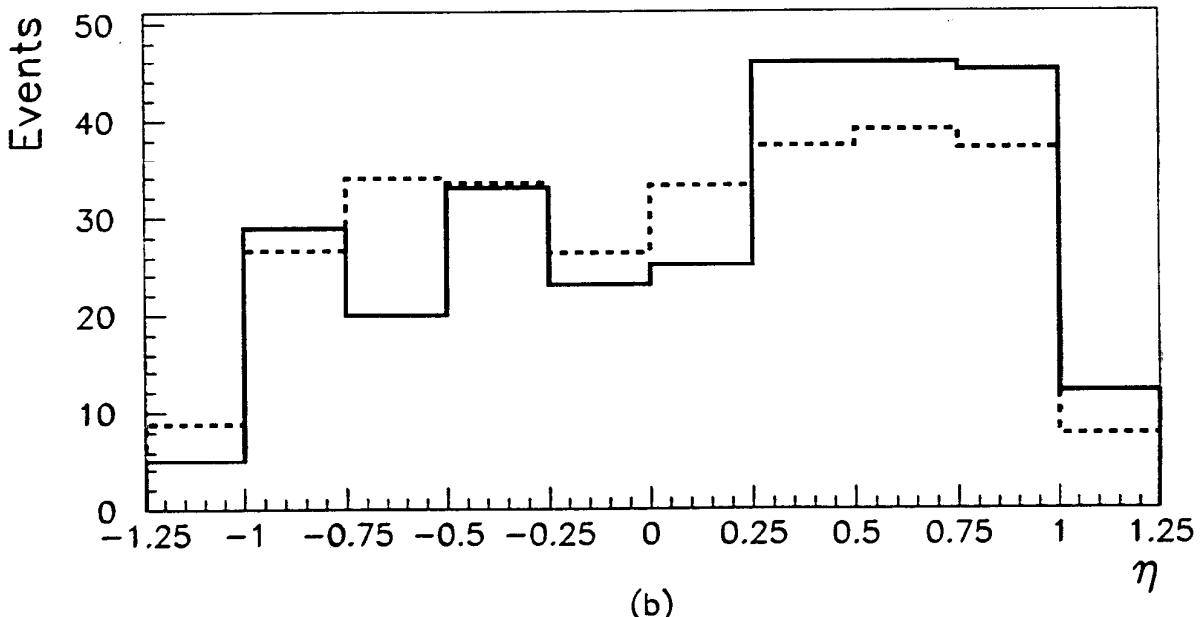
diff (b+c) \sim 60% of sample

e⁺ sample
with gap

CDF preliminary



(a)



(b)

Figure 17: (a) E_T spectrum of the diffractive electron candidates with SVX track (solid) and non diffractive low multiplicity sample(broken). The fraction of diffractive heavy flavor is estimated to 60%. (b) η distribution of the diffractive electron candidates with SVX track (solid) and non diffractive low multiplicity sample(broken). East gap events are overwritten with fliped sign.

Roman-Pot Triggered Data

Data Sample

Tevatron run 1C (Fall/Winter 1995/96)

1800 GeV special low luminosity (few $10^{29} \text{cm}^{-2}\text{s}^{-1}$)

2.8 million diffractive triggers

Event Selection

single vertex — remove multiple interactions

$0.05 < \xi < 0.10$ and $|t| < 1 \text{GeV}^2$ — good roman-pot acceptance

two jets with $E_T > 10 \text{ GeV}$ — definition of dijets

After Cuts

2 million roman-pot triggered events (inclusive)

2500 diffractive-dijet candidates $E_T > 10 \text{ GeV}$

Diffractive Topology Evidence

rapidity gaps in forward detectors on pot side

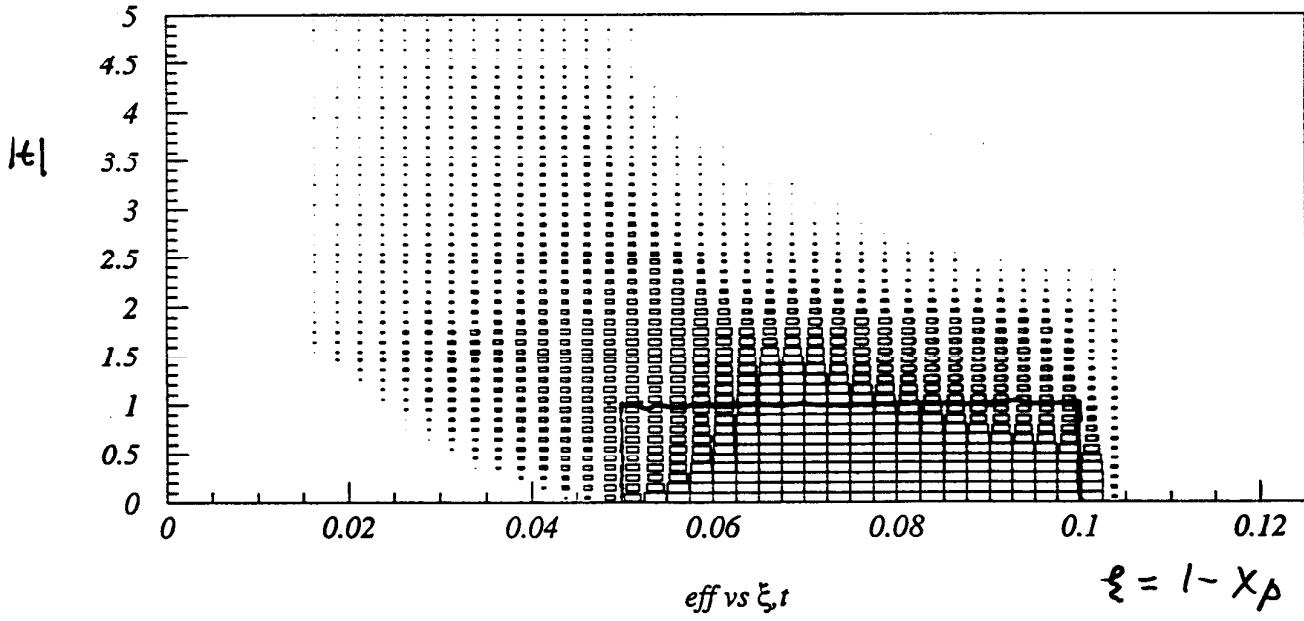
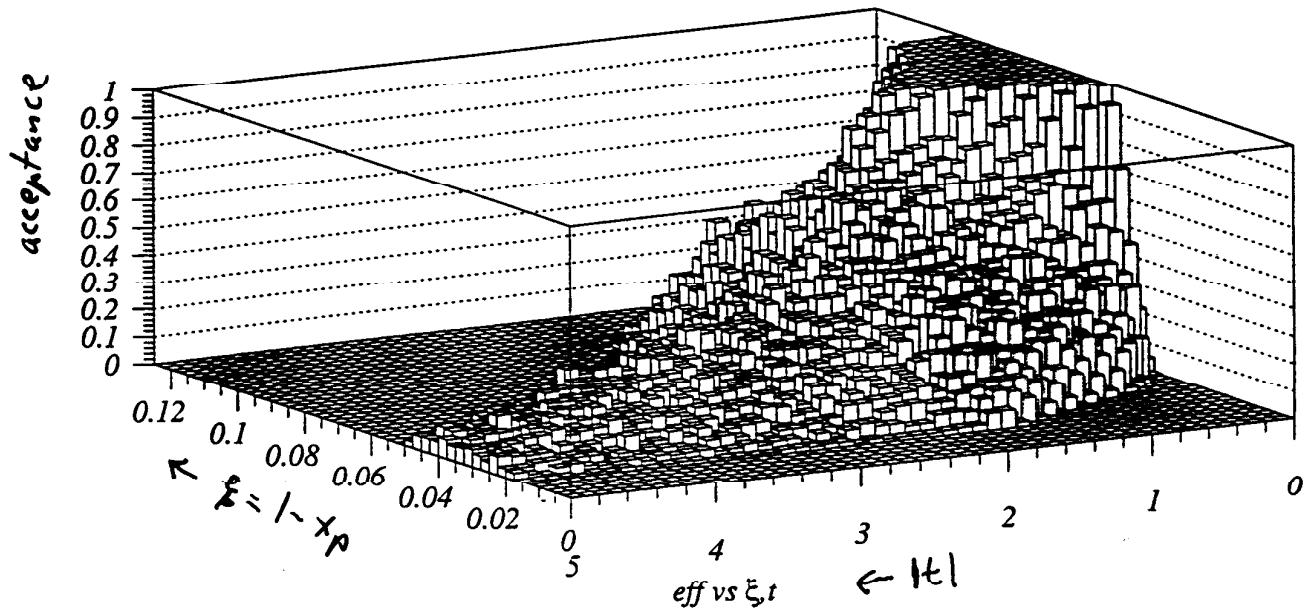
lower center-of-mass energy

event is boosted away from Roman pots

ξ is correlated with Mass and η_{max}

Efficiency

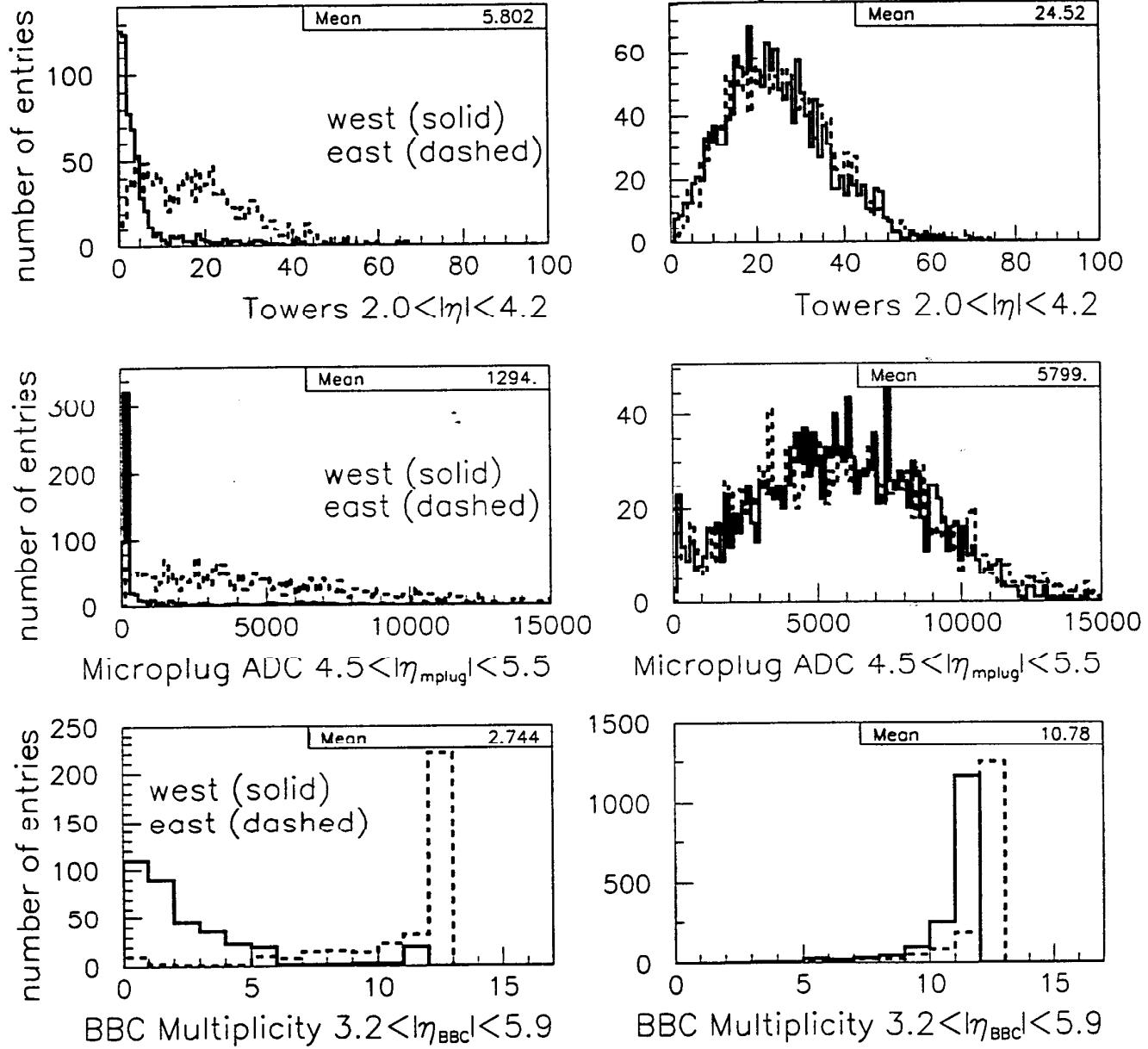
09/08/96 16.14



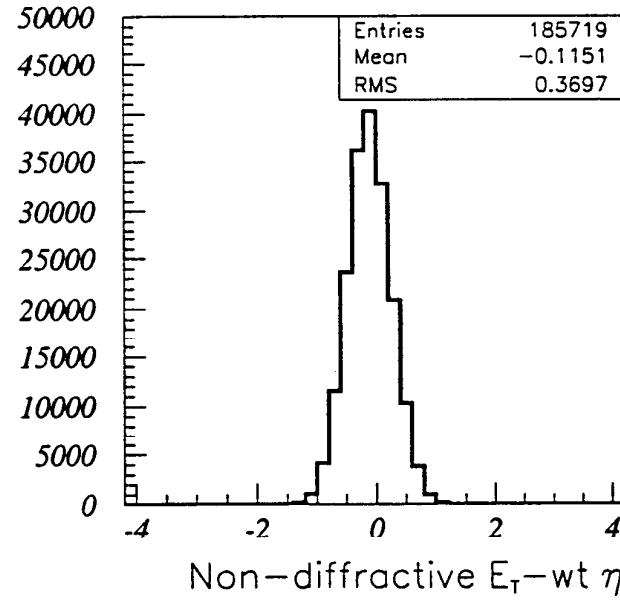
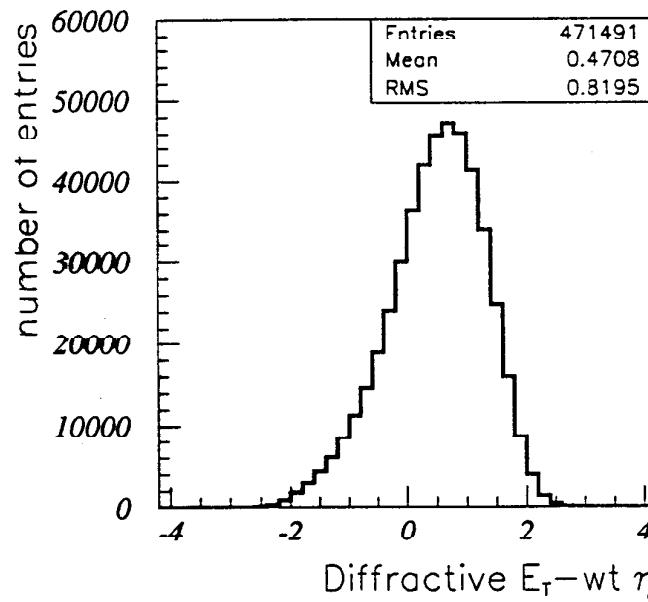
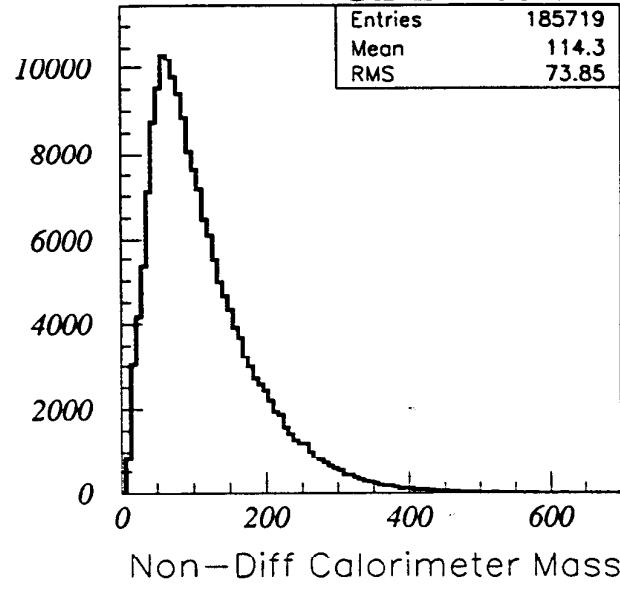
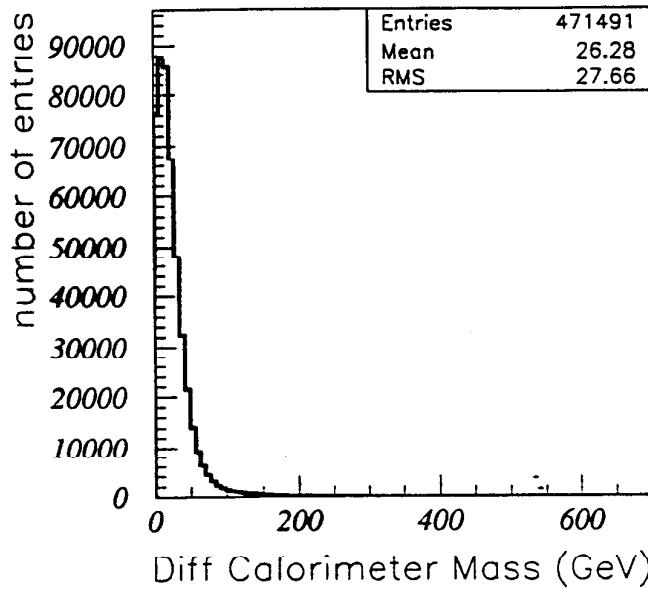
$$0.05 < (\xi = 1 - x_p) < 0.10$$

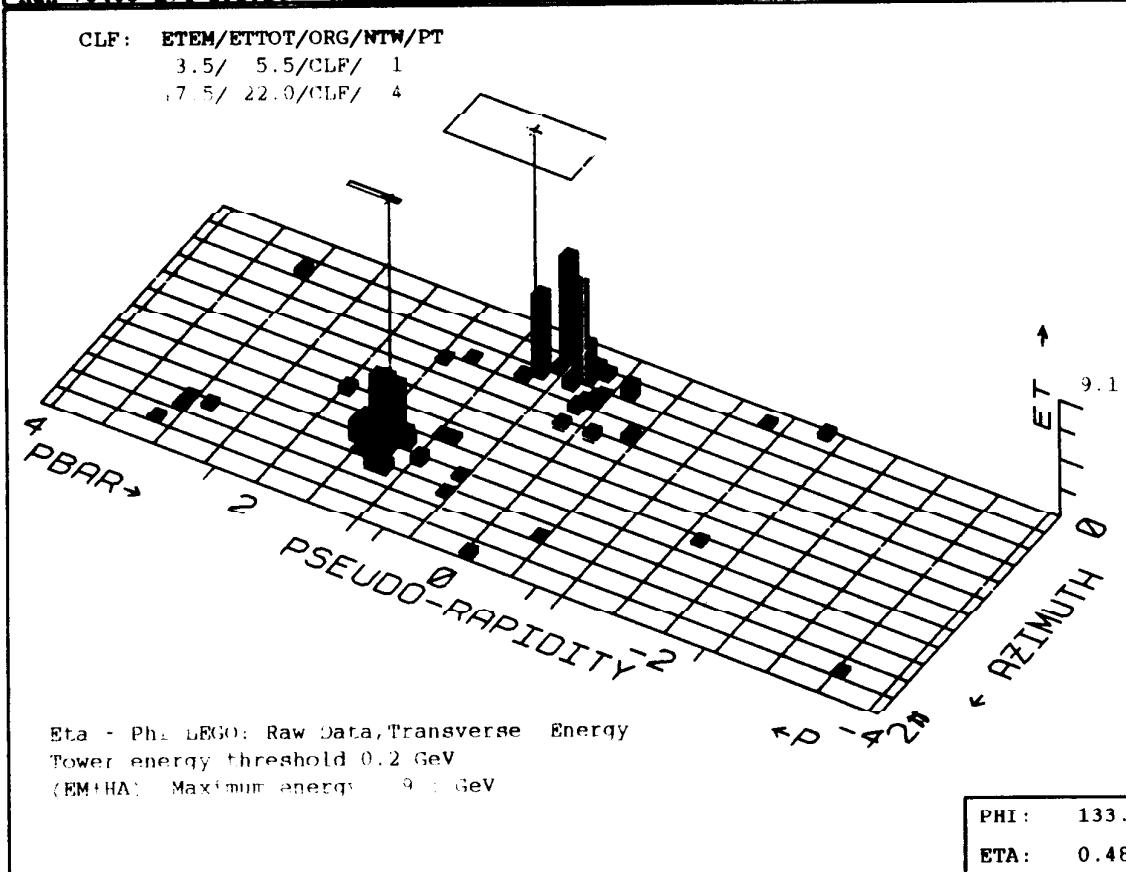
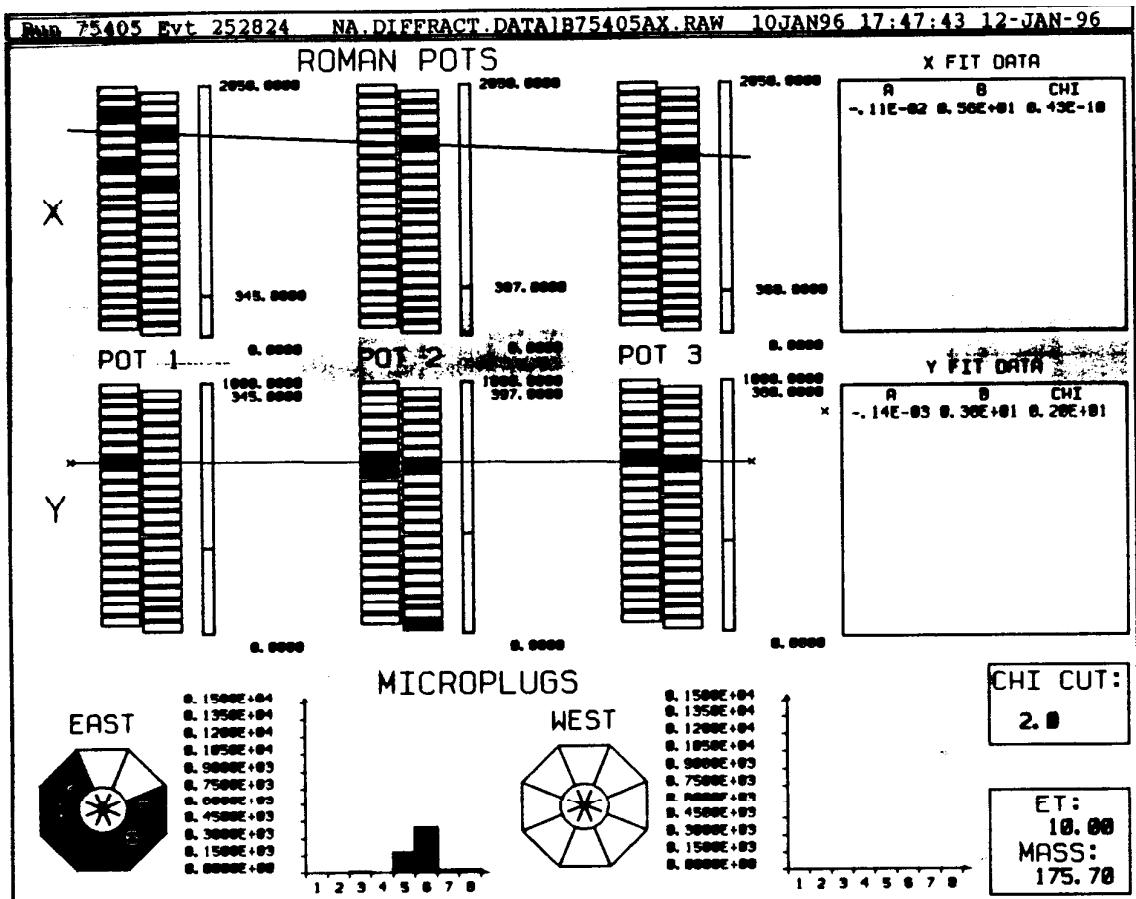
$$|t| < 1 \text{ GeV}^2$$

Diff-dijet Candidates Rapidity-Gap Evidence CDF Preliminary



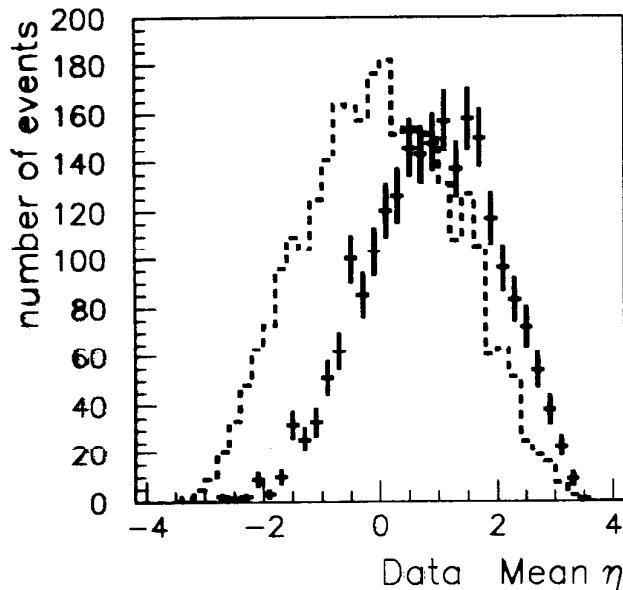
Inclusive-Diff Calorimeter Mass and E_T -weighted η CDF Preliminary



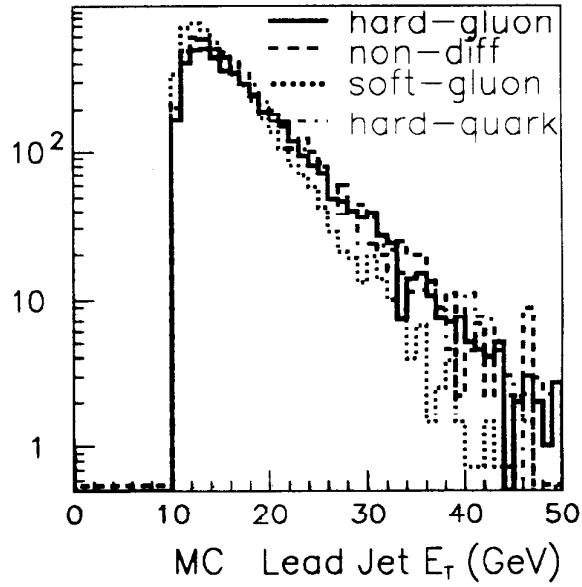
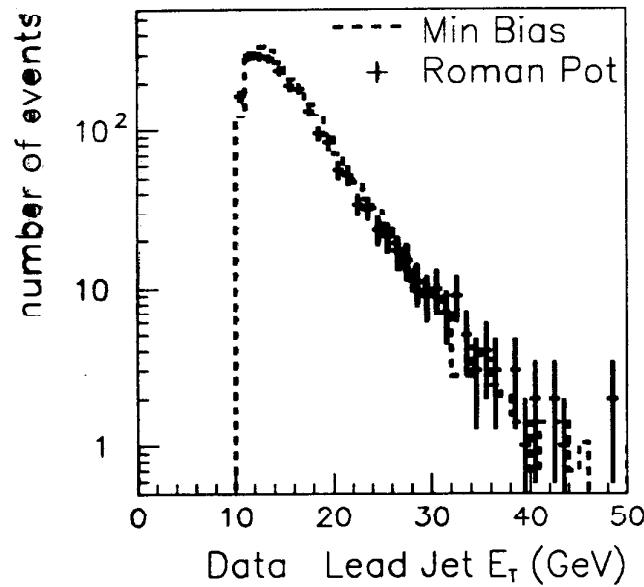
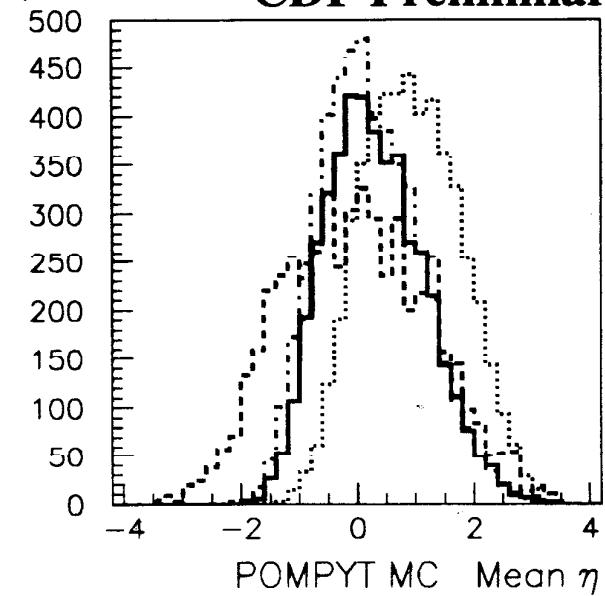


Roman Pot Dijets $E_T > 10$ GeV

$(E_T > 10 \text{ GeV}, 0.05 < \xi < 0.10, |\eta| < 1 \text{ GeV}^2)$

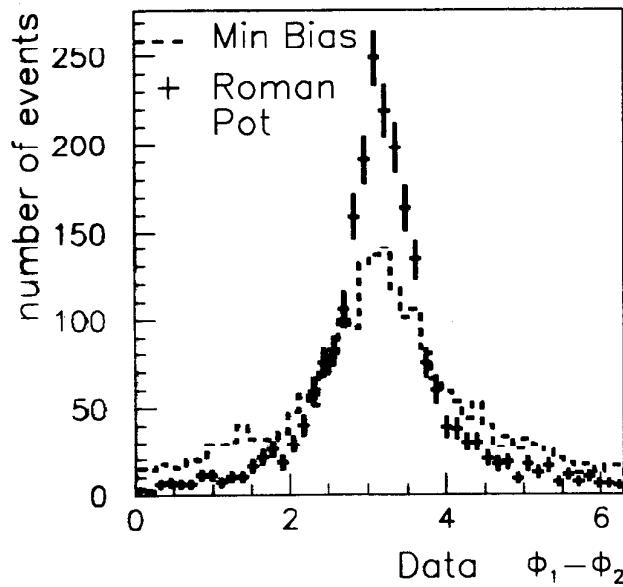


CDF Preliminary

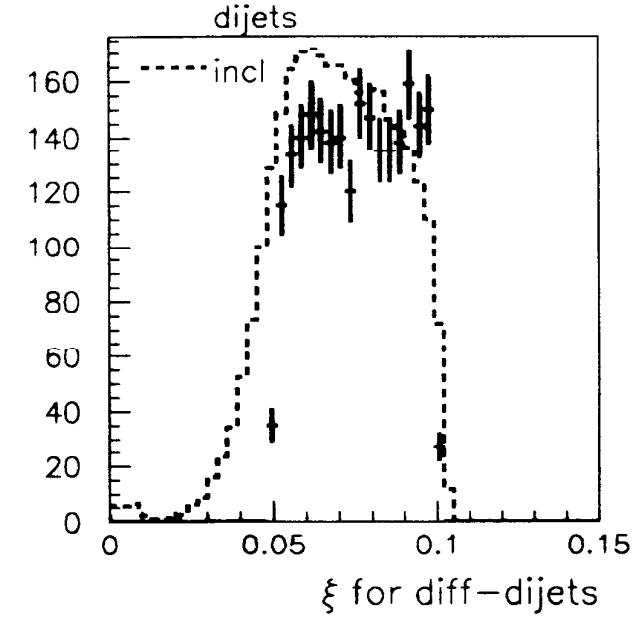
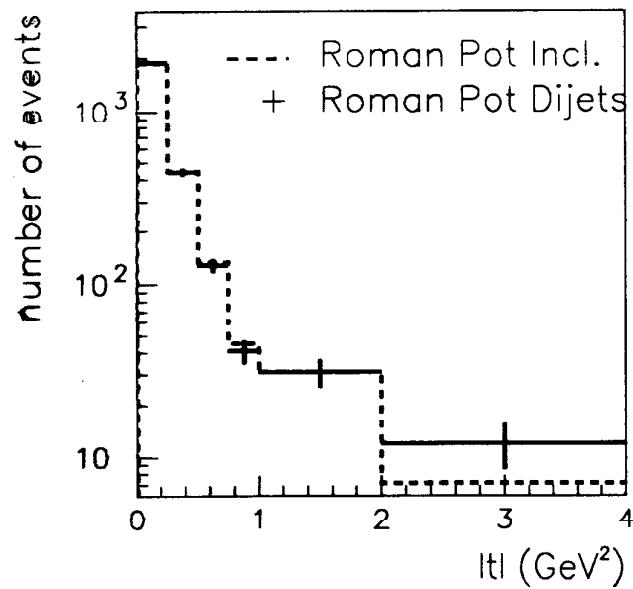
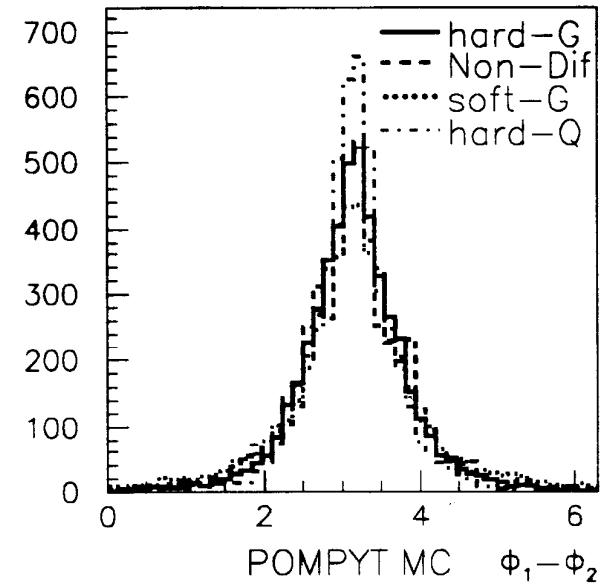


Roman Pot Dijets $E_T > 10$ GeV

($E_T > 10$ GeV, $0.05 < \xi < 0.10$, $|t| < 1$ GeV 2)



CDF Preliminary



Dijet Data

Monte Carlo generation with CDF detector simulation

POMPYT Hard Gluon (Quark) with $6\beta(1 - \beta)$ pomeron*

POMPYT Soft Gluon with $6(1 - \beta)^5$ pomeron*

PYTHIA non-diffractive

* Standard flux $\frac{\text{d}\sigma}{\text{d}\Omega}$

Dijet Rates

Correct dijets for selection efficiency and
normalize to inclusive Roman pot events.

0.18% of inclusive

$\sigma_{pot} = 0.64 \text{ mb}$ ($1/3$ pomeron-induced) for $0.05 < \xi < 0.10$

$\sigma_{pot jet} \sim 1 \mu\text{b}$

Present Diffractive/non-Diffractive Ratio

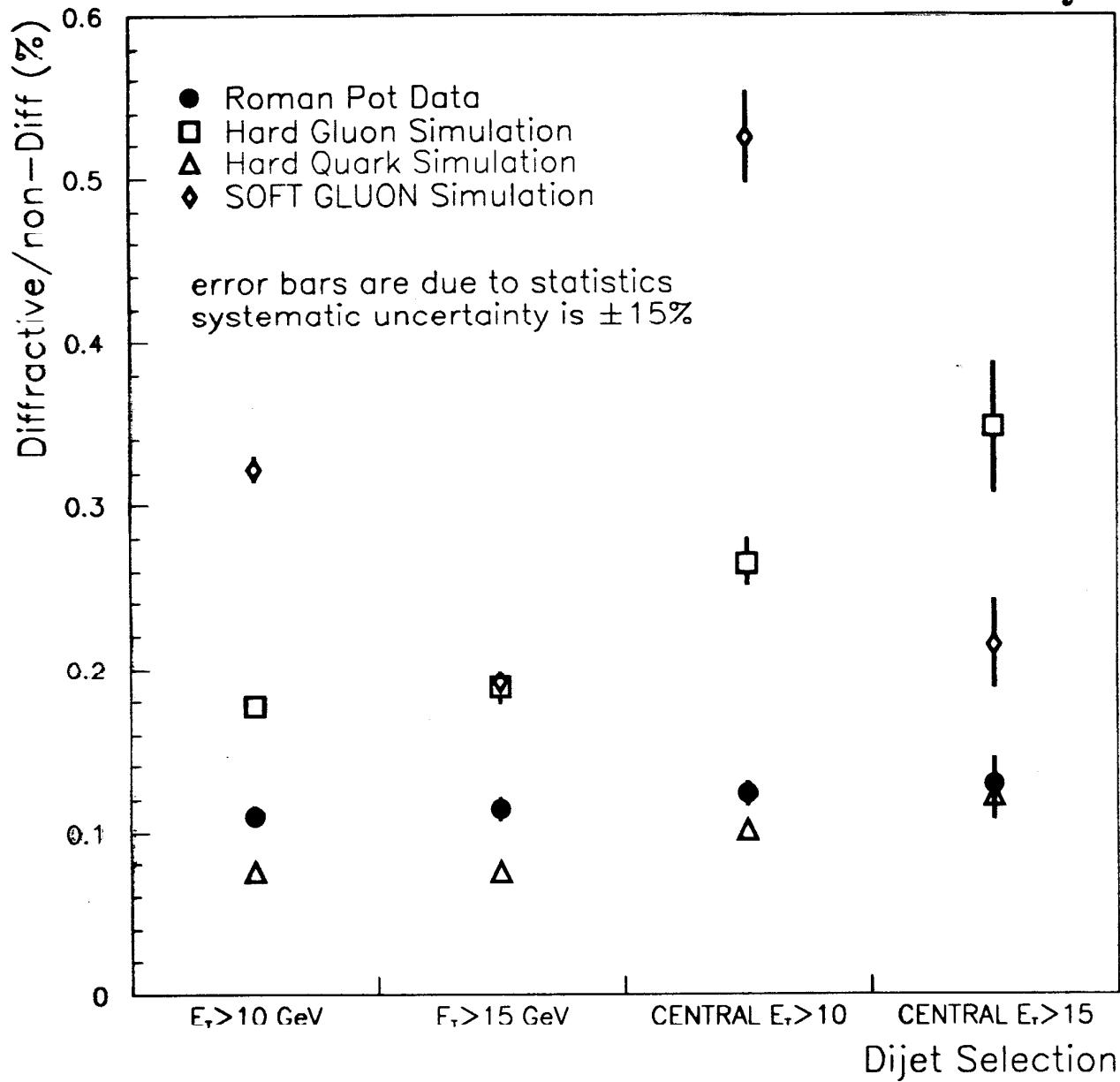
Ratio reduces normalization problems for data and Monte Carlo.

Diff/non-Diff ratio = $[0.109 \pm 0.003(\text{stat}) \pm 0.016(\text{syst})]\%$

$E_T^{\text{jet}} > 10 \text{ GeV}$

Ratio of Diffractive to Non-Diff Dijet Rate

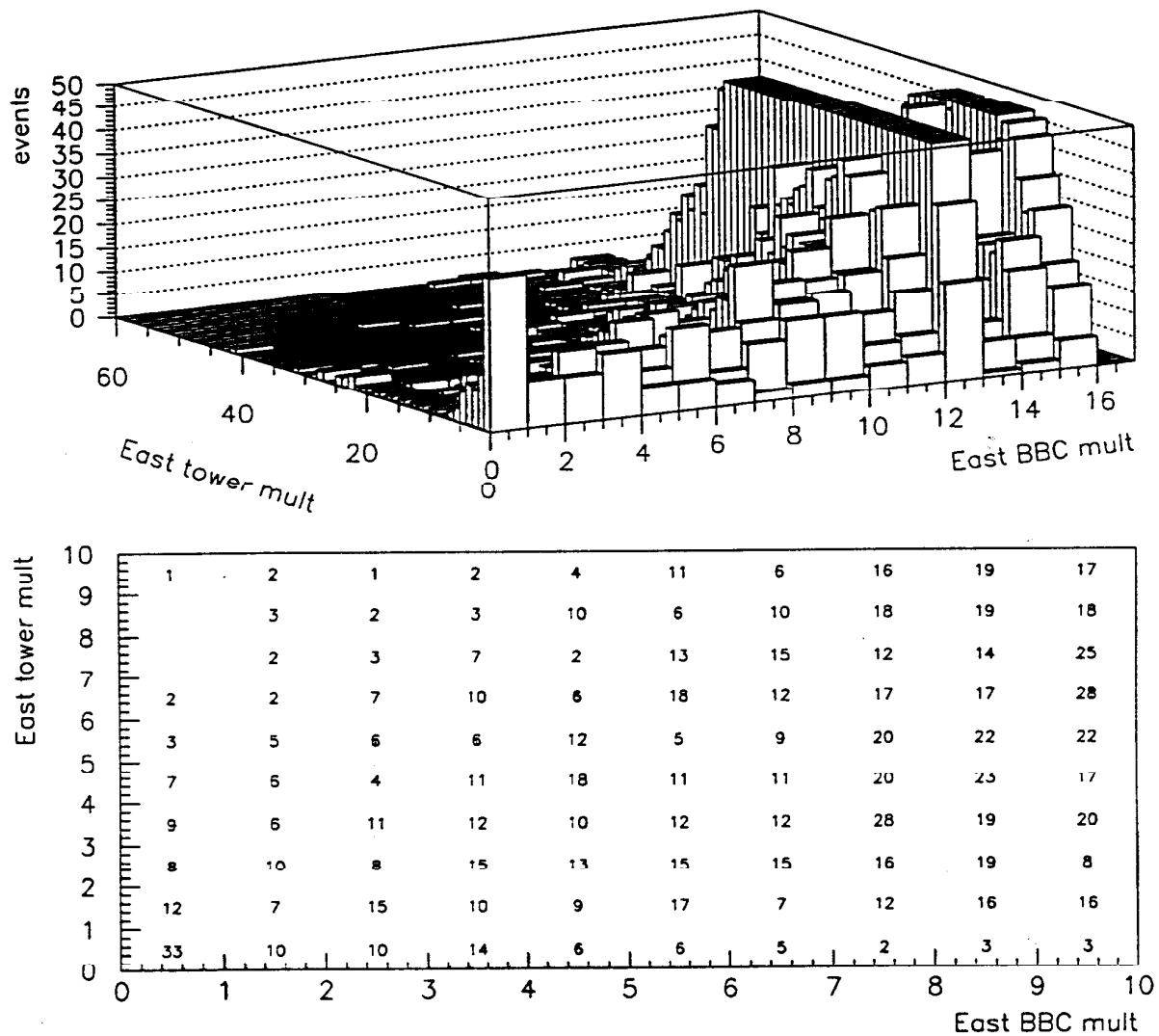
CDF Preliminary



Roman Pot + Gap Dijets $E_T > 7 \text{ GeV}$

PB

(Double P)



$$\text{Signal} = (1.70 \pm 0.36 \pm 0.24) \times 10^{-3} \text{ of SD}$$

(Roman pot dijet)

Figure 3: Roman pot 7 GeV dijets: east BBC versus towers ($2.0 < \eta < 4.2$). There is a clear excess of events with BBC=0 and tower=0 which is interpreted as the double pomeron signal.

Double Pomeron Dijet Results

Roman pot trigger: $0.05 < \xi < 0.1$ $0 < |t| < 1 \text{ GeV}^2$

Dijet $E_T > 7 \text{ GeV}$

- Ratio of single diffractive to non-diffractive rates

$$R_{SD/ND} = (1.60 \pm 0.02 \pm 0.24) \times 10^{-3}$$

- Ratio of double pomeron to single diffractive rates

$$R_{DP/SD} = (1.70 \pm 0.36 \pm 0.24) \times 10^{-3}$$

- Ratio of double pomeron to non-diffractive rates

$$R_{DP/ND} = (2.7 \pm 0.6 \pm 0.6) \times 10^{-6}$$

SUMMARY OF HARD DIFFRACTION RESULTS

1. Diffractive W Production

$$R_W = (1.15 \pm 0.55)\% \\ (\xi < 0.1)$$

2. Diffractive Dijet Production

$$R_{GJJ} = (0.75 \pm 0.10)\% \\ (E_T^{jet} > 20 \text{ GeV}, |\eta^{jet}| > 1.8, \eta_1\eta_2 > 1, \xi < 0.1)$$

3. Diffractive Heavy Quark Production

$$R_{HQ} = 0.18 \pm 0.03(\text{stat})\%$$

5. Dijets with $E_T^{jet} > 7 \text{ GeV}$ in:

Single Diffraction (SD): $0.05 < \xi < 0.1$

Double-Pomeron Exchange (DPE): $0.05 < \xi_1 < 0.1, \xi_2 \sim \xi_1$

Non-Diffractive events (ND)

$$\begin{array}{ll} \text{DPE/SD} & [0.170 \pm 0.036(\text{stat}) \pm 0.024(\text{syst})]\% \\ \text{SD/ND} & [0.160 \pm 0.002(\text{stat}) \pm 0.024(\text{syst})]\% \\ \text{DPE/ND} & (2.7 \pm 0.7) \times 10^{-6} \end{array}$$

The Structure of the Pomeron

1. The low fraction of diffractive $W + Jet$ events observed indicates the presence of a hard quark component in the pomeron structure.
2. From R_W and R_{JJ} , the hard gluon content of the pomeron is determined to be (independent of the pomeron flux normalization)

$$f_g = 0.7 \pm 0.2$$